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WHY IS INVASIVE SPECIES EDUCATION IMPORTANT

by

Alexandra N. Crofts

A capstone submitted in partial fulfillment of the requirements for the degree of Master of Arts in Education: Natural Science and Environmental Education.

Hamline University

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"Of all the questions which can come before this nation, short of the actual preservation of its existence in a great war, there is none which compares in importance with the great central task of leaving this land even a better land for our descendants than it is for us."
Theodore Roosevelt, 26th President of the United States of America

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CHAPTER ONE

Introduction

For as long as I can remember I have cherished nature and wildlife. I am lucky enough to have a burning passion for something specific, which has driven my personal and professional goals to be one in the same. I want to make a difference in the developing world to benefit nature and the environment because we have recently lost the value in protecting our land and wildlife. Time in nature is the first thing to be replaced by technology. Humans are spending less time outside and more time in front of screens. I want to foster an appreciation of the world and it's biodiversity as it occurs naturally because that is something we cannot replace once it is gone. In this capstone I will be answering the question: *why is invasive species education important?* I worry there is a lack of knowledge about aquatic invasive species (AIS) within the general public from professional and personal experiences in the field of environmental education. General knowledge about introduced species is crucial to protecting the integrity of any ecosystem, as they can have a drastic impact. Robert Ricklefs and Rick Relyea evaluate this process in *Ecology The Economy of Nature,* " In general, introduced species that compete with native species rarely cause extinction of native species whereas introduced species that act as predators or pathogens on native species can cause large population declines and extinctions of native species" (Ricklefs & Relyea, 2014). I have always been thankful for my infinite love and curiosity for the environment because it has kept me determined to achieve many personal and professional goals, for reasons beyond my own well being. I want to educate people about AIS to encourage appreciation and

preservation of wildlife and their natural habitat. As many seem to agree, some are saying it is time to protect and appreciate the natural spaces and shorelines on our Earth because once they are gone, with rare exception, they are gone for forever (Louv, 2005). In this chapter I will tell you about my personal and professional journey that has ultimately led me to where I am today.

Personal Background

My journey began long ago as a child playing in the woods and exploring the pond in front of my house, where I grew up in Southern Connecticut. My earliest memories are full of bullfrogs croaking loudly at night, deer silently passing through the yard, catching glistening fireflies, and watching baby snapping turtles hatch. What I realize now is that the amount of wildlife that surrounded me, as soon as I stepped out my backdoor, is what sparked my initial interest in the outdoors. We would build forts in the woods, catch frogs, go fishing, and watch chrysalis' and cocoons hatch to see what they turned into as spring and summer activities. Sometimes we would hold on to the animals temporarily as our own little wildlife collection, only to return them where they came from in the ponds and streams later that day. One of my all time favorite childhood memories was when my neighborhood best friend and I thought we discovered a new species (ironically right in my front yard). We sat in silence studying and observing the animal, not wanting to disturb the biological course of nature. In all of our excitement we ran to tell our parents, who had to inform us that it was just a female wood duck (*Aix sponsa*). At that age, we were only familiar with the mallards we saw regularly. This memory will stick with me forever because it supports the theory that nature inspires curiosity, questioning, and creativity even at the youngest ages. I have never let go of

those pure moments in nature, experiencing awe and wonder caused by the animals that I lived right next to. Exposure might be the key to appreciation. We face many challenges in today's world, such as urban environmental education. How do we encourage growth and questioning about the natural world and wildlife to a ten year old who has grown up in New York City and never stepped foot into a forest, on a boat, or even into Central Park? I have faced similar challenges on a daily basis while working at zoos and aquariums. It is no simple task trying to convince people to care about endangered species that live halfway around the world from them. Exposure to the beautiful natural world is what caused my passion and appreciation for the environment at a very young age and I will continue to pursue my passion for the benefit of future generations to come in hopes that they might feel the same way I do one day.

Besides my own property with woods and freshwater ecosystems, I also lived just a few miles away from the beach on Long Island sound. My favorite thing to do growing up was run, walk, or bike down to the beach and meet up with friends and family. This opened my eyes to the magic underwater world that lied just beyond the shore of the Ocean. This was an entirely new ecosystem to explore, play in, and make lifelong memories. My love for water and aquatic ecosystems has only grown since then and I have obtained my SCUBA license to create new memories and experiences in the Ocean. At the beach we observed gulls and cormorants hunting, caught crabs, threw seaweed at each other, and returned jellyfish back into the sea that had washed up. Along with these memories from home, I also visited some of the best National Parks in our country at a young age like Yosemite, Rocky Mountains, and Olympic National Park with my family. These travels have encouraged some other bucket list goals in my life, like to visit all 50

states. As I am well on my way to accomplishing this task, sometimes it is nice to take a step back and appreciate all the breathtaking land and ecosystems that have already successfully been protected in the U.S. We have many previous influential leaders to thank for these sites like Woodrow Wilson and Theodore Roosevelt. Both presidents who acknowledged the importance in our innate and primal connection with the land we call home and depend on for survival.

Undergraduate experience. I have a background of volunteering at aquariums and zoos, college summer internships, and temporary jobs since graduating with my Bachelors degree. It was a demanding schedule to major in Biology as a Division 1 student athlete in Women's Lacrosse for University of Connecticut. Fitting in four-hour labs and daily lectures every week around lifting, conditioning, practice, and traveling was quite the challenge. I learned incredible time management, organizational, and leadership skills during my time at UCONN that I will utilize forever. I matured on and off the field throughout those four years and once again, my passion and determination grew stronger for a career helping the environment. At one point in my undergraduate education, my academic advisor recommended I consider changing my major to something "easier" than Biology, which only fueled my fire. I was determined to raise my grades in the classroom and my athletic performance on the field. I successfully did both by the end of my four years receiving academic and athletic accolades from the Big East Conference just before my career ending knee injury. Countless physical therapy sessions and two years later, now with a strong repaired knee I look forward to spending more time in the field for research opportunities I previously had to miss out on.

As an aspiring environmentalist I want to ensure the general public is being educated about the world and it's natural resources. I want to draw attention to how we treat the Earth because some mistakes are irreversible. My eyes were opened to the wonderful professions that lie ahead when I was in high school and started volunteering at the nearby aquarium. I loved learning about all of the animals in the aquarium, the ocean ecosystems, and having the responsibility of contributing to the guest's experience at the aquarium. I realized very quickly this field of work was my passion because it was the only other thing that interested me outside of playing sports. Later on in college I returned to the aquarium for a summer college internship. I learned all the behind the scenes of the facility and assisted in daily feeding and cleaning of the tanks and animals. I helped the aquarists maintain and provide enrichment to their collection. It was a great experience working like an aquarist a few months to see what the entire profession is like. I learned so much about the Long Island sound from working there, it made me realize how precious the beach is and how crucial it is to keep it healthy and clean. I went on to tell all of my friends and family what I had learned so I could teach them to care about these natural habitats as much as I did. It makes my time I spent volunteering at the aquarium even more special to know we are protecting critical habitat in the Ocean. I went on to do more job shadows and internships at zoos and aquariums where I gained more experience like this in the field.

Professional Journey

Later on I interned at a non-profit wildlife rehabilitation center. This gave me an entirely new outlook into wildlife care because of how different it was from the other experiences. At this point, I learned an immense amount of knowledge about wildlife

medical care and gained handling experience on the most common birds found in Minnesota. I learned how to administer medicine orally and other common health care protocol that involved getting the patient healthy and released back into the wild. This was a very rewarding experience to be able to participate in the rehabilitation of sick, stranded/orphaned, or injured wildlife.

I also worked as a field technician on a plant/soil feedback experiment one summer. This taught me about numerous different grass species and the relationship between soil and plants. These were long hot sunny days in the field working to maintain over 2,500 plots and collecting samples. This was a perfect temporary experience to understand what it is like to conduct fieldwork research on a long-term (five year) project.

Since then I've also held an Interpretive Naturalist position in an outdoor butterfly garden. Once again, I learned an unprecedented amount of knowledge about something I had never worked with before, this time relating to Lepidoptera (moths and butterflies). This was an amazing experience because I also got to promote pollinator conservation to the guests visiting the garden exhibit. This allowed me to draw connections to the food we eat everyday to the insects that were flying around their faces. People have a hard time caring about what they do not know about. I enjoyed passing out seed packets that included native plant seeds with good nectar sources so visitors could enjoy their own butterfly garden at home and simultaneously provide more habitat and food sources for pollinators. We educated guests on how climate change is impacting our pollinators and about many species that are endangered due to habitat loss. Even without an entomology background, this experience was very fulfilling. I felt like I was having a positive impact

by educating guests about the importance of pollinators and what everyone can do to help them. We sparked interest in these insects by educating guests about their interesting facts and then relating it to our own lives. We have the ability to extend their natural habitat by planting native plants that are good nectar sources for those insects in the wild, instead of planting brightly colored genetically modified annuals that do not have nectar sources. I enjoyed advocating for the smaller animals that often get overlooked because the impact they have on our daily lives is not as obvious to most.

I also was a Public Educator at a zoo. This job allowed me to interpret all the plants and animals found at the facility to visitors and answer questions from inquisitive guests. The main purpose of this job was to educate and spread conservation messages to visitors. I created public programs/educational talks on Polar Bears, Orangutans, and Snow Leopards so guests could learn about these species more in depth. As I mentioned, all of the programming encourages environmentally conscious choices and life styles. I explain what the major threats are to these populations in the wild and how every single one of us can make a difference. I offer guests a number of ways to limit their greenhouse gas emissions by carpooling and using public transportation, lowering the thermostat, turning off all your lights when not in use, and many other simple decisions that can be made every day. Orangutan's (and many other species) biggest threat as a critically endangered great ape is habitat loss and fragmentation. I recommend downloading a free app on your phone that allows you to scan barcodes or search the product by name to tell you whether or not the company is using sustainable palm oil in their products. We want to decrease the amount of products we purchase that use unsustainable palm oil because that directly correlates to the loss of Orangutans natural habitat. After all these jobs and

experiences, I still have the same exact goal, to promote the conservation and preservation of the natural world and wildlife. The biodiversity of the world is what makes it such a fascinating place to live after all.

During this thesis process I was able to intern with the Minnesota Department of Natural Resources (MN DNR) in the East Metro St. Paul Office in the Fisheries Area. This allowed me to participate in standardized lake population surveys, index of biological integrity surveys, assist in the hatchery, stock lakes, collect samples for contaminant testing, and represent the MN DNR at environmental educational events like the at fish pond in the MN State Fair Exhibit. My research revolved around monitoring native fish populations to see if historic records correlate with the presence of AIS having a negative impact in these freshwater ecosystems. My hope is to find correlations between these species that would assist environmental education efforts to inform the general public and water recreationalists about the proper behavior when interacting with AIS. Future environmental education plans can become more specific and localized based on the results of this study, as it pertains to bodies of water found in the Twin Cities metro area. Finding more specific relationships between aquatic invasive species and our native fish populations would allow us to spend more time, money, and research efforts on the most destructive one. Each individual invasive species, animal or plant, will impact our native ecosystems differently.

Conclusion

Rationale. I am obtaining my Masters degree as an aspiring naturalist and environmentalist. I am still in the middle of my professional, personal, and academic journey, which I have high hopes for. This Master's degree will help me qualify for very

competitive positions in environmental work that I have always desired. I will conduct MN DNR standardized lake surveys in the East Metro region of the Twin Cities and cross run that data with the establishment of AIS in those lakes to help me answer the question *why is invasive species education important?* In Chapter Two I will review literature that supports my case, that invasive species can drastically alter an ecosystem and cause major declines in native populations and increasing awareness/education of AIS will help keep the freshwater ecosystems of Minnesota safe. In Chapter Three, I will describe the methods I use to collect my data samples and I will draw a conclusion of my thoughts in Chapter Four by analyzing the data I collected in May-August 2018. In Chapter Five I will settle on conclusions tied together by this thesis process studying AIS in Minnesota. Educating the general public about AIS will allow them to participate in the prevention of spreading AIS and have positive interactions with nature and wildlife. My hope for the future is to achieve a societal outlook that will start making decisions that put the environment first, instead of ourselves.

CHAPTER TWO

Literature Review

In this chapter I will review literature on environmental education, aquatic invasive species, and the current conservation efforts surrounding those themes. I am examining literature on these topics to help gain insight on the research question that will be answered in this capstone thesis: *Why is invasive species education important?* Increased environmental education about aquatic invasive species (AIS) for the general public could successfully prevent the spread of these species throughout Minnesota's freshwater ecosystems. I am analyzing environmental education methods, techniques, and previous research from all over the country to draw connections and conclusions to see what has been successful in this field so far.

I analyze aquatic invasive species research and records to determine what negative side effects are caused by AIS in freshwater ecosystems and how that applies to Minnesota's aquatic ecosystems. I consider what AIS infest Minnesota's water currently, and what has been done to try and eradicate those species. I am also interested in investigating what conservation efforts have been tested in Minnesota and how effective they have been so far. Everyone in Minnesota needs to know what AIS are to be able to consciously prevent the transfer of these species throughout the waterways. If they do not know, anglers and recreational boaters will not be able to properly interact with them when they come across them during recreational activities and could naively transport them to other bodies of water accidentally. If the general public does not know the impact AIS can have on their ecosystems, they might be less likely to act on the prevention of them. By collecting and analyzing resources on these topics I will be able to evaluate how

environmental education in Minnesota pertaining to aquatic invasive species can be improved.

Environmental Education

Society is constantly in a state of motion on our planet, with a multitude of moving parts that create our finely balanced world. Environmental education is not only supposed to teach us about our physical environment but also how to live sustainably (Monroe & Kransy, 2015). Most agree that the goals of environmental education are to provide every person with the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment (Monroe & Kransy, 2015).

There are numerous reasons to emphasize environmental studies throughout education, but one factor is the changing climate. According to Saylan, Blumstein and Blumstein, most people are aware of the threats facing our Earth and humanity's future due to increased levels of carbon dioxide emissions, however most communities have not taken enough action to decrease those CO2 levels and slow the decreasing biodiversity rates (2011). If current estimates of melting permafrost are accurate, some billion of tons of methane will be released into our atmosphere, which would out shadow any attempt society has made to decrease CO2 emissions (Saylan, Blumstein, & Blumstein; 2011). Saylan, Blumstein and Blumstein said the collective inability to act on this is in part due to educational institutions that do not provide students with the proper tools to think critically and understand the modern world, nor do they teach individual responsibility or social engagement skills (2011).

Richard Louv, author and environmentalist, drew a lot of attention to the changing societal habits involving more time indoors and excessive amounts of electronics in his

well-known publication of *Last Child in the Woods*. Louv said that if we want to save environmentalism and the environment, we must also save an endangered indicator species: the child in nature (Louv, 2005). The mere presence of an indicator species typically gauges the health of a particular habitat and is considered a diagnostic of communities and environmental conditions (Ricotta & Carboni, 2015). Humans, as an indicator species, inhabit almost every inch of the Earth at this point. For example, think of an abandoned city without humans. This is an example of a habitat without it's indicator species, which would mean the health of that environment is at risk. The indicator species is imperative to the functionality of the ecosystem. This needs to be the viewpoint with humans in nature as well. If there are no longer children, adults, and families playing outside and spending quality time in nature, then the health of our outdoor environments are at risk.

Children spend less time playing outdoors these days and miss out on life-long memories and defining moments, according to Louv a generation of children are now being raised indoors (2005). He also coined the term nature deficit disorder in families, individuals and communities, "It describes the costs of alienation from nature, diminished use of the senses, attention difficulties, and higher rates of physical and emotional illness (Louv, 2005, p. 36). It is crucial to draw the parent's attention to the studies that have revealed that children in 'green day cares', who play outside everyday regardless of weather, had better motor coordination and more ability to concentrate (Louv, 2005). It is part of an environmental educators job to communicate with the student's parents to help them understand the mental, physical, and emotional health benefits from connecting with nature. Louv says that, "New studies suggest that exposure to nature may

reduce the symptoms of Attention Deficit Hyperactivity Disorder (ADHD), and that it can improve all children's cognitive abilities and resistance to negative stresses and depression" (2005, p. 35).

Environmental education practices are put to use in everyday lifestyles all over the world. Specifically, urban environmental education can come in many forms at zoos & aquariums, nature centers, formal urban K-12 education, industrial facilities, parks, and many other locations (Russ, 2015). Especially in urban settings, participants in the environmental stewardship trend make direct improvements to their urban ecosystems or maintain those ecosystems to provide multiple benefits to urban residents (Russ, 2015). It has been found that environmental education in urban settings is crucial to connecting those communities to the outdoors, since they do not usually have interactions with nature on a daily basis. Louv offered another opinion, "Unlike television, nature does not steal time; it amplifies it. Nature offers healing for a child living in a destructive family or neighborhood" (Louv, 2005, p. 7). Many times there is less opportunity for people living in urban environments to connect with nature, so urban environmental education programs are crucial to their exposure.

According to Russ, individuals with limited exposure interpretations are based on what they learned from indirect sources like horror movies, amusement parks, television, and zoos (2015). These falsities can cultivate a fear and disconnect them from the outdoor world. Spending unstructured time in natural spaces offers a wide range of benefits for people of all ages according to Louv. Playing and exploring in nature as a child enhances all of the senses, which promotes creativity and intellectual development (Louv, 2005).

My research question investigates a similar predicament on a much smaller scale, environmental education teachers and interpreters should steward curiosity and interaction with nature for the benefit of the land and wildlife. Some people are aware of problematic AIS, but there have not been enough steps taken to make a positive impact. Researchers have seen the same response to warnings about climate change with awareness and action that has not yielded major results. Hopefully, if more awareness is drawn to the issue there will be a more urgent response from the general public.

Environmental education in Minnesota. According to *Natural Wonders: A guide to early childhood for environmental educators*, which was collaboratively written by many environmental educators in the Twin Cities of Minnesota, many are realizing and now arguing that free time in nature is crucial to early childhood learners (2002). Even though by early childhood age, students already have minimal outdoors time if they are in a regimented preschool. It may be limited to only a few minutes a day in a fenced in area on a blacktop with minimal natural elements (Oltman, 2002). It is important for children to have unstructured time in nature because it contributes to their physical, emotional, and social development by offering rich and dynamic exploration that can increase their confidence, comfort level, and coordination (Oltman, 2002). There is no reason to wait for the significance of unstructured nature play to be established or accepted in society. The research has already shown the positive effects of simple natural spaces. Dauntingly, sometimes parents do not encourage outdoor play because they do not see the significance and value in it (Monroe & Kransy, 2015).

A study was conducted to evaluate the level of natural play in Minnesota licensed preschool facilities in 2010. All of the 81 respondents indicated having outdoor playtime

in their daily schedule, however 92% reported their outdoor play space was on playground equipment (Ernst, 2010). None of them reported using untamed or natural areas for the majority of their outdoor playtime, so very little if any of this can be considered nature play (Ernst, 2010). This draws attention to the difference of playing outside (on playgrounds) and abstract nature play. Many of the health benefits observed from previous research rely heavily on unorganized free time in a natural location. The study on Minnesota licensed preschools research concluded that out of 81 respondents, only about half (41 of 81) are including 60 minutes or more of outdoor play in their daily schedules (with 26 of those 41 including this amount only when they consider it "nice" outside) (Ernst, 2010). In conclusion, there appears to be a need for increasing the amount of time spent for outdoor play, and potentially increasing the amount of time spent in outdoor play during seasons/weather not perceived as nice (Ernst, 2010).

A statewide study was conducted in Minnesota of 32 counties on the impact of their environmental education field trip programs. According to Carlson, "Environmental field days require investment of money, staff, time, and energy in program planning and presenting" (2008), so educators and school administrators would like to know if these trips are effective for learning purposes. In Minnesota, these trips educate over 10,000 4th-6th grade students about issues related to our natural resources, environment, and conservation (Carlson, 2008). Field settings can help improve teaching methods and students learning when it directly correlates to the topic being studied and the outdoor location (Carlson, 2008). In Minnesota, environmental field day programs were identified in 66 of the 87 counties (76%) (Carlson, 2008). Program profiles reveal that partnerships are crucial to success and continuation of environmental field days, because of the

surveyed programs, 67% relied heavily on in-kind donations (Carlson, 2008). This might be the case because the value in these trips are not being recognized enough to encourage permanent funding.

Direct and frequent experiences in nature early on in life help foster positive attitudes towards the environment that develop at a young age (Monroe & Kransy, 2015; Oltman, 2002). This means that there needs to be active attempts at finding a solution to getting early childhood students outside more often and in more natural settings for their own mental and physical health benefits. Nature play also encourages physical activity interacting with the environment like running around in fields, jumping on rocks and logs, and throwing leaves. Environmental educators need to take every opportunity to bring positive experiences in nature to these students everyday because it might be the only exposure they are getting. Fostering an appreciation for nature early on in life will lead to more environmental activists in the future. However, there are many challenges educators face when trying to implement something new to their classes or curriculum like environmental education.

Barriers of environmental education. Since the beginning of the environmental movement within the U.S. perception of the environmental education principles have been debated throughout school systems, leaving it as a controversial topic. According to Shaw, teachers sometimes feel uncomfortable and pressured to teach complex environmental issues that are not in their field of expertise, when really they should simplify their focus to science-based nature education (2003). For example, the challenge is seeing the value in time spent in nature to make those insect lessons come to life off of the paper and outside of the classroom. Like any other aspect in education, it pertains to a

specific audience and age group. According to Oltman, sometimes teachers stay within their comfort zone of teaching styles, using props or scripts instead of allowing personal discovery, interaction, and relationship building (2002; Russ, 2015). On another note, Monroe and Kransy believe, controversial topics that are still being currently studied and investigated by scientists should be avoided with young children (2015). At a later age, high school and middle school students can grasp at these unsettled issues by learning to develop arguments based on facts (Shaw, 2003). Debate and discussion can help students recognize the continuous reexamination of the progress of science based on fact and interpretation (Shaw, 2003).

According to Saylan, there also is the looming negative outlook that environmental education is failing, as education so far has not created enough change in the attitudes to act on the decreasing biodiversity, effects of climate change, and degradation of the environment (2011). If society fails to bear the moral responsibility to protect the resources that support life on our planet not only for us but also for the future generations to come, they fail humanity (Saylan et al., 2011). Saylan says schools must become places where students learn to value diversity and learn skills to live involved lives and teach ecology as the overall system we exist in (2011).

Environmental education faces many challenges to date. It is not always a priority globally, nationally, or locally, and it can be left out of policies or remain unfunded when policies do not exist (Monroe & Kransy, 2015). That is why environmentalists take the opportunity to represent the wildlife and natural land that cannot advocate and protect itself. A study by the Center on Education Policy in 2008 revealed that teachers attempting to comply and meet state and federal standards, had to cut out environmental

education, social studies, and other non tested subjects to spend more time on high stakes testing subjects like reading and math (Monroe & Kransy, 2015). This outlook on the lack of importance of environmental education is wide spread.

Current research trends are showing societal changes in perception of the outdoors, "Of the mothers interviewed, more than 80 percent cited concerns over crime and safety as obstacles to their children's time outdoors. Parental lack of time and a lack of supervision outdoors were also noted as major barriers" (Monroe & Kransy, 2015, p. 135). Unfortunately, studies show danger is a growing fear and barrier in urban settings as well. Students surveyed in an urban environmental education program described their fear of locations immediately outside of their apartment building and beyond where they played, primarily about getting robbed or kidnapped (Russ, 2015) Crime and violence, specifically murder and rape, along with the anticipation and fear that dangerous people are hanging out by the trees, has created an uncomfortable relationship with nature (Russ, 2015). It is our privilege as environmental educators to create a safe and welcoming setting in natural areas to allow positive interactions with the outdoors. There are also many possibilities that some of these links can be connected to the changing technological advances (Monroe & Kransy, 2015).

Another indicator researchers have felt is important is the usage of our National Parks, "A 2005 study found that decreased attendance to National Parks in the United States over the previous 16 years correlated with increased time spent with electronic media such as video games, watching TV and movies, and surfing the Web" (Monroe & Kransy, 2015, p. 49). It is not to say that technology is to blame for these trends, but it provides insight into the relationships between society, technology, and the natural world.

There are many more distractions to take up free time indoors than previously ever before. It is suggesting people are choosing to engage in other activities, rather than spending that same free time visiting natural locations. People used to look to the outdoors for entertainment and wonder, and as studies are showing our interest in these natural places are significantly decreasing as time goes on.

The decreasing trend of park visitors has prompted other questions as well. An environmental education study was conducted in Colorado evaluating the impact interpretive signs have in natural areas on their guests. The point of this study was to weigh the pros and cons of interpretive signage in parks and natural spaces. The main investigation revolved around the signs impact, effectiveness, and if the visitors liked them. Of the large observation group, 427 visitors to the park, majority did not spend any time visiting interpretive signs along their walks, hikes, and bike rides (Davis & Thompson, 2011). These results yield information that interpretive educational signage in natural spaces might not be as impactful as originally thought, and most times are expensive. However in certain circumstances like at Cathy Forme Prairie, 95 percent of interviewees successfully identified the habitat as short grassland prairie (Davis & Thompson, 2011). This shows that interested visitors do benefit from the interpretive signs found in parks to learn about these locations and habitats. Interviews that were conducted showed that first time visitors pause to read interpretive signs more often than repeat visitors (Davis & Thompson, 2011). Of guests who do stop to read the signs, knowledge obtained from the signs varied from location to location. This leads to more questioning, how can environmental signage appeal to the returning visitors audience. Of 77 references to favorable features, three-dimensional and interactive attractions were

mentioned the most (Davis & Thompson, 2011). This would be an interesting research concept to apply to AIS interpretive signs found at lakes and public boat launches to see how it impacts public perception, attitude, and preventative behaviors.

Another problem environmental education is facing is the lack of commonalities in the lessons being taught between the educators, the students, and their home lives (Blanchet-Cohen & Reilly, 2013). A study was conducted in a Quebec urban high school with high student diversity. The main challenges they learned about were a lack of common lived experiences, reconciling contradictory educational perspective and political policies, which often led teachers to paradoxical positions (Blanchet-Cohen & Reilly, 2013). This controversy and lack of experience in teaching environmental education topics leaves some teachers uncomfortable and unconfident in the classroom. When educators feel uncomfortable talking about diversity, they skip over it or ignore it and this leads the students to believe that there is something wrong with those differences (Oltman, 2002). As many of those working in these settings have had little formal environmental education, they may feel stressed and isolated from other professionals with similar interests (Monroe & Kransy, 2015). Educators all over the world must embrace this new adventure of advocating for the environment, for the benefit of us all. As time goes on, environmental education should be implemented regularly in curriculums and encourage connecting students with natural experiences.

A case study was conducted in Israel of a longitudinal study of the school's culture involving outdoor environmental education as a critical part of their science education at an elementary school (grades 1-6). Tal and Morag believed they observed one of the major common problems of environmental education programs worldwide,

they are often extra-curricular, interdisciplinary, and occasionally planned by informal organizations that make them fragile and dependent on the existing personnel (2013). This research seems to show a lack of commitment to implement environmental education in the school curriculum permanently. According to Tal and Morag, one major weakness of environmental education is the lack of research and evidence from the field that could shed light on environmental education practices and their place in a school curriculum (2013). These practices and environmental education programs could be seen as much more valuable than they are currently viewed with further research on environmental education practices and programs throughout the world.

It is challenging to fight for the necessity of environmental education when there has not been an overwhelmingly positive amount of observed outcomes. Even though environmentalists are actively searching for solutions everyday, the degradation of the environment is not waiting for society to catch up. There is always a time and a place to teach, and as the physical world continues to change due to anthropogenic impacts, there is a need to put more emphasis on environmental education. If there were no environmental movement to begin with, the planet would be in even worse condition than it is today. There is now access to endless knowledge and answers to all questions right at our fingertips everyday, but there in lies the problem: What people chose to do with that powerful and influential technology is what matters most. However, many think at this point environmental education needs to become more effective immediately.

Invasive Species

Environmental education is a very broad topic with a variety of categories. Within this context, AIS education can provide a path to changing societal behaviors and

opinions to benefit the local aquatic ecosystems in Minnesota. The threat of the possible loss of biodiversity due to invasive species dominating ecosystems all over the world is daunting. The more educators and parents that encourage environmental education involving AIS, the more comfortable people will be interacting with these infested bodies of water and the species that live there.

If a species did not historically exist in its given location, it is considered introduced, exotic, or non-native (Ricklefs & Relyea, 2014). Studies on AIS are informative because an introduced species that spreads rapidly and negatively affects other species can become invasive, which is why my capstone will answer the question *why is invasive species education important?* While biotic homogenization threatens unique niches, research will continue to help preserve the natural habitats of the world. Biotic homogenization is a process by which unique species compositions originally found in different regions slowly become more similar due to the movement of people, cargo, and species (Ricklefs & Relyea, 2014). One main reason continued AIS research is necessary is to actively prevent the spread of established invasive species to protect the native species residing there. A great example of their devastating implications was when the Nile Perch was introduced into Lake Victoria in East Africa. They annihilated the native community of cichlid fishes, driving many to extinction (Almalfitano, Havel, Kats, Kovalenko, Thomaz, 2015). Preventing AIS from spreading and continuously altering aquatic ecosystems requires more research, education, and dedication to save and preserve niche biodiversity.

This is not an easy challenge to accomplish, “According to the Center for Invasive Species and Ecosystem Health, North America currently has a large number of

invasive species that include nearly 200 pathogens, 300 vertebrates, 500 insects, and 1,600 plants" (Ricklefs & Relyea, 2014). The only way to prevent these species from spreading further is to educate the general public about the risks these species pose and attempt to change their behavior, which could lead to actively preventing the transfer of them to new bodies of water.

Aquatic invasive species. There are invertebrate, vertebrate, and plant aquatic invasive species found in bodies of water all around the world. A study conducted in Yellowstone National Park showed results that non-native fish species could cause a decline in native fish populations (Syslo, et al., 2010). This study explored the problems caused by introduced lake trout, which threatened native Yellowstone cutthroat trout populations in Yellowstone Lake. After concluding human interference was necessary for the benefit of the aquatic ecosystem, they began a removal process of the non-native species. The objective of many fish removal projects intends to reverse the declining native fish populations caused by invasion of non-native species (Syslo et al., 2010). It is an immense challenge to remove an apex predator from an ecosystem in an attempt to stabilize the trophic levels. Even with a decade of active removal the lake trout populations were still increasing, however they would have been much higher without an attempt at lake trout suppression (Syslo et al., 2010). This demonstrates how well established AIS can become in their newly introduced habitat relatively quickly.

The invasion of a species can spiral out of control rapidly. Once established in one freshwater ecosystem, AIS can be spread more-easily to other nearby lakes and the chance of colonization of these species increases (Almalfitano et al., 2015). Once an invasive species is established in an ecosystem it is very challenging to eliminate them

because of their ability to adapt. However, eradication and control are more likely to succeed if an introduced species is detected early, when its abundance is low and its spatial distribution is restricted (Hoffman, Kelly, Peterson, Trebitz, & West, 2010). A study conducted in Canada suggested similar findings, that the smaller the population of non-native species are, the more likely it is to be able to control the invasion. While reduced genetic diversity does not appear to prevent universal invasion success, low genetic diversity may increase the probability of invasion failure (Fisk, Health, Wellband, & Pettitt-Wade, 2016). These statements support that the smaller the population of AIS is, the better chance we have to containing and eliminating its presence where it does not belong. This brings a new challenge into consideration, how to manage and effectively survey invasive species populations.

The increased species dispersal worldwide has been greatly accelerated by humans (Almalfitano, 2015). Aquatic ecosystems seem to be at particular risk from invasive species because of threats to biodiversity and human needs for water resources (Almalfitano, 2015). With more attention drawn to AIS problems and more education dedicated to protecting our ecosystems, the probability to perverse these natural habitats is much more likely. Minnesota's waterways currently suffer from a number of AIS, some being the zebra mussel and common carp.

Aquatic invasive species in Minnesota. As already stated, AIS can have a wide-ranging effect on ecosystems and trophic cascades. It is recognized that invasiveness of fish commonly depends on local abiotic conditions and biotic resistance by native competitors and predators (Bajer & Chizinski, 2012). Common carp (*Cyprinus carpio)*, a species found in Minnesota's waterways, is one of the most invasive fish species in the

world, having been introduced onto to every continent besides Antarctica (Bajer & Chizinski, 2012; Wahl & Wolfe, 2011; Matsuzaki, Takamura, Usio, & Washitani, 2008). The wild carp species is considered to be native to Japan, but the Eurasian domesticated type had been introduced for aquaculture purposes (Matsuzaki et al., 2008). When you take into consideration that this invasive fish species can exist and thrive on every continent (besides Antarctica) you realize how impressive its adaptability is. This means it takes environmental education and societal contribution to change behaviors and prevent the spread of this species in the future. These efforts must become priority because we already know that carp can have success in almost any ecosystem in the world and unfortunately, also have the ability to outcompete native fish species. There are many trophic interactions in aquatic ecosystems and each component of the food web is affected by adjacent trophic levels. This means that the prey carp feed on directly are not the only species impacted by their presence. Research suggests they have bottom- up impacts in the aquatic ecosystems they inhabit (Matsuzaki et al., 2008).

In a study in Japan, carp populations affected zooplankton, macrophytes, and phytoplankton and altered the habitat as ecosystem engineers. They found that carp have negative impacts on benthic macroinvertebrates, which are small aquatic animals that live at the bottom of rivers, lakes, and streams. They suppressed seedling emergence of aquatic plants (macrophytes) from seed banks and reduced worms (Oligochaeta) and non-biting midges (Chironomidae) density (Matsuzaki et al., 2008). However, their presence significantly increased zooplankton and phytoplankton due to altering the water quality of the enclosure (Matsuzaki et al., 2008). This display shows how drastically AIS can alter an ecosystem by its invasion. It not only decreases some species populations,

sometimes by direct predation, but by altering water quality it can cause other species to increase. Invasive ecosystem engineers not only modify or destroy the habitat of other species, but they also alter the flow of nutrients, physical resources or energy, and change the character of the invaded space (Matsuzaki et al., 2008). This is why AIS research is crucial to finding out more information on how these species change the ecosystem them invade.

In Dundee, IL a research project was conducted to evaluate invasive carp effects on aquatic ecosystems. Overall, the research yielded results of limited growth of juvenile native (centrarchids) fish species that were present (Wahl & Wolfe, 2011). At the end of the 60 day experiment, turbidity and phosphorus levels were increased in the water and juvenile bluegill and largemouth bass grew significantly slower with common carp present (Wahl & Wolfe, 2011). Thus, they concluded that common carp have a large impact on the food web throughout the aquatic ecosystems and alter the trophic level interactions (Wahl & Wolfe, 2011). This is why AIS education in Minnesota is imperative to keeping our freshwater ecosystems healthy and eliminating AIS before they drastically alter the niche biodiversity.

Another AIS study on young of the year (YOY) carp was conducted in the Upper Mississippi River basin and interconnected lakes. YOY are fish that have not turned one year old yet. Their study focused on variation of biotic resistance exerted by native predatory species and whether or not that impacts their spawning success. Results showed that YOY carp were only found in shallow waters that experience winter hypoxia (winterkill) and low densities of the native egg predators in the local aquatic ecosystems (Bajer & Chizinski, 2012). A follow up experiment also showed that these eggs survived

in winterkill lakes, but they only survived in non-winterkill lakes when protected by mesh netting that excluded fish. They concluded, “Large numbers of carp eggs were found in the stomachs of native fish inhabiting lakes that did not winterkill. We conclude that common carp, and likely many other highly mobile and fecund invasive fish, have evolved life histories to avoid egg predators and can become invasive when they are absent” (Bajer & Chizinski, 2012). This is another example and display of the common carps ability to adapt and have success in a variety of aquatic ecosystems. Their ability to spawn in specific locations to avoid predation of their unprotected eggs lead them to have more success in reproduction and establishing populations in new waterways. This is another reason it is a major challenge to prevent the spread of AIS into other Minnesota lakes and waterways, as they have the ability to survive and spawn under a multitude of conditions. However, carp are not the only AIS Minnesotans have to worry about.

Zebra mussels have been present in North America and reported in Minnesota since the mid 1980s (Johnson, Riccardi, & Carlton, 2001; Kanankege, Alkhamis, Phelps, & Perez, 2018). The first introduction of this species is due to ballast water from transatlantic ships (Kanankege et al., 2018). This rapidly spreading bivalve has potential to effect animal and plant health of aquatic ecosystems, just the same as other AIS. Zebra mussels have already infested thousands of miles of U.S. waterways, altering ecosystems and generating in excess $60 million per year in economic damages to water intake systems, waterfront properties, bridges, and infrastructure (Adams & Lee, 2011). Aquatic invasive species education is thought to assist in the prevention of the spread of these AIS with boaters and anglers.

Previous research has shown how zebra mussels can invade, alter environments, and act as ecosystem engineers. Places with high densities of zebra mussels, like Lake Erie and the Hudson River, can filter most of the algae out of the water column, leaving little food for the zooplankton. Zooplankton need access to resources since they act as a primary component of many fish species diet. This decrease in algae increases light for vascular plants, which causes more growth and changes to the habitat structure (Almalfitano, et al., 2015). This completely changes the balance of the ecosystem they invaded and impacts all of the native species located there.

The sheer number alone is cause for concern. Once zebra mussels have colonized a lake they can reach densities between 10,000 and 700,000 per square meter, up to 100-fold higher than in their native range, most likely due to the lack of native predators and competing species (Colborne, Clapp, Longstaffe, & Neff, 2015). Zebra mussels proliferate and establish quicker than native freshwater mussel populations (Seekamp, McCreary, Mayer, Charlebois, Hitzroth, & Pasternak, 2016). The high density of their populations cause major changes to the aquatic ecosystem and food web by filtering excess amounts of water. By minimizing food sources at the lowest level of microorganisms, it impacts zooplanktivorous fish and larger species (Colborne et al., 2015; Seekamp et al., 2016). This consequently impacts all other aspects of the food web by changing resources in the given habitat.

Animals are not the only type of aquatic invasive species damaging aquatic ecosystems in Minnesota. Eurasian watermilfoil is an aquatic invasive plant species found throughout North America (Moody, et al., 2016). The invasion of Eurasian watermilfoil is thought to have originated on the U.S. Eastern Seaboard and is now one of

the most economically costly plant invasions for control and management in North America (Moody, et al., 2016). It is thought that eurasian watermilfoil was introduced into North America through aquarium trade (Kanankege et al., 2018). Eurasian watermilfoil's native range is throughout Asia, Europe, and Africa. However, since being introduced to North America it has hybridized with a native species, northern watermilfoil (Moody, et al., 2016). Since this AIS invasion involves hybrid genotypes of Eurasian and northern watermilfoil it makes identifying, controlling, and managing very challenging. According to the Minnesota Department of Natural Resources (MN DNR) Eurasian watermilfoil was first established in Minnesota in Lake Minnetonka in 1987 (2018). Eurasian watermilfoil poses many threats to Minnesota's water such as: dense mats at the water's surface that inhibit water recreationalists, overtakes habitat and outcompetes native plants (lowering diversity), and provides unsuitable shelter, food, and nesting habitat for native animals (DNR, 2018). However, less than seven percent of Minnesota's more than 11,000 lakes are on the infested waters list (DNR, 2018).

Aquatic invasive species education. One of the most important tools in the world is knowledge, which is why I believe environmental education is imperative to preventing the spread of AIS where they do not belong. The point of AIS education is to reach out to the people who come in contact with AIS and have the ability to take preventative measures. Water recreationalists regularly come in contact with these species and participate in activities that can contribute to the spread of AIS. Given that AIS prevention is much less expensive than response, campaigns have been developed to target recreational water users and to try to change public behaviors to prevent recreational introduction and spread of AIS (Seekamp et al., 2016). I am interested in

how successful AIS education has been so far and whether or not it has yielded positive responses.

A survey about AIS was conducted in the Great Lakes region of Michigan. The AIS of most concern for this region include a few I have already discussed, such as Asian carp, zebra mussels, eurasian water milfoil, and the spiny water flea (Seekamp et al., 2016). In general respondents rated themselves slightly to moderately knowledgeable about AIS (Seekamp et al., 2016). "Draining" was the most common AIS prevention method performed by water recreationalists followed by the "inspect and remove" recommended behavior (Seekamp et al., 2016). Knowledge of the "Stop Aquatic Hitchhikers!" (SAH!) Campaign was also tracked. Overall, 55% of water recreationalists were familiar with SAH! and positively correlated with increased AIS knowledge and personal responsibility to reducing the spread of AIS (Seekamp et al., 2016). This is a great sign to see that AIS education does have a positive impact with recreational boaters and anglers. There is a need for more data to be collected in this field to analyze how effective these measures can be.

A study was conducted in the Great Lakes and Finger Lakes region of New York. The main focus of this study was to measure public perception/attitudes, knowledge of, and support for management techniques and policy approaches regarding AIS and comparing results from a lake that had active AIS education and programming and a lake that did not (Sharp, Cleckner, & DePillo, 2016). This kind of research is necessary to know how much of an impact AIS education can have on their targeted audiences, which are mostly recreational boat users. The opportunity strongly exists for the transport of AIS from the lake if the boat owners do not take proper means of care (Sharp et al.,

2016). How can a boat owner actively prevent the spread of AIS if they do not know what they are, what they look like, or that they are a present threat? The reality of the situation is that water recreationalists have to be educated about theses species and participate in the recommended preventative behaviors. Of the survey participants in this study, 71% stated they had seen, read, or heard, about AIS in the past twelve months (Sharp et al., 2016). The majority of respondents recognized AIS as a problem and expressed urgency in regards to management of invasive species (Sharp et al., 2016). Approximately the same percentage of respondents actively participates in a solution to the problem by inspecting their own boats (Sharp et al., 2016). This shows that most people in the Finger Lakes and Great Lakes region of NY who enjoy the freedom of recreational water usage feel the need and responsibility to keep it healthy and clean. These participants could possibly be determined to do so for their own recreational desires, but regardless of whatever the motive is it still protects the ecosystem. In this study, only 2% of respondents indicated that boat inspections would be unacceptable in all cases (Sharp et al., 2016). The overwhelmingly large pool of respondents who felt the need for AIS management supports the actions and attempts to decrease the spread of AIS in recreational water users. Even though this is great display of positive attitude, there are other human vectors that transfer AIS as well.

A study was conducted of in-trade hobbyists in eight states within the Great Lakes Region (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin). The release of aquatic organisms-in-trade by aquarists, gardeners, and outdoor pond owners has been recognized as an AIS vector within the U.S. (Seekamp, Mayer, Charlebois, & Hitzroth, 2016). In 2004 a U.S. Fish and Wildlife Habitattitude

campaign was developed to encourage self-regulation by aquarists, gardeners and outdoor pond owners, but little was known about its impact. They surveyed their recognition of the Habitattitude campaign and their personal compliance of recommended behaviors for organism's purchase and disposal (Seekamp et al., 2016). In general they found that recognition of the Habitattitude campaign was low, however respondents who owned an aquarium and outdoor pond or water garden were significantly more likely to be aware of the campaign than respondents who only participated in one hobby (Seekamp et al., 2016). This is likely due to increased exposure to the Habitattitude campaign from multiple venues like tradeshows, in stores, and at expeditions (Seekamp et al., 2016). Hobbyists rated Habitattitude campaign posters, informational brochures, and pet store personnel as the most effective at distributing campaign materials (Seekamp et al., 2016). This research is necessary to make improvements moving forward in AIS educational prevention methods and campaign attempts. It is important to get feedback from the target audience to gauge how effective the campaign was and whether or not it is having a positive impact. These efforts are being put to use truly for the conservation of biodiversity and health of our aquatic ecosystems. With that being said, further research and analysis is necessary to weigh the pros and cons of each AIS educational campaign and its potential positive impact. It must produce a positive impact in preventative efforts to be worth all the time and money put into the creation and advertisement of the campaign.

Conservation

Ecologists realize the only effective means of preserving the diverse species of the world is through conservation of ecosystems and the management of large-scale

ecological processes. This includes species that humans depend on for food sources and other products, which in turn are dependent on the maintenance of their environmental support systems (Ricklefs & Relyea, 2014). Many of us want to preserve what naturally occurs on this Earth, however due to external stresses we commonly make choices that do not put the environment first. A study was conducted in Minnesota surveying private lakeshore property owners. They were interested in better understanding the protection and removal of native aquatic plants by Minnesota lakeshore property owners. The loss of native aquatic plants can have consequences on the entire lake ecosystem, but the existence of these plants on personal property can be viewed positively or negatively by property owners (Schroeder & Fulton, 2013). Their findings supported the hypothesis that disadvantages of aquatic plants were consistently negatively related to behavioral norms, attitudes, and behavioral intentions for their protection (Schroeder & Fulton, 2013). The strongest belief noted from the evaluation was that removing aquatic plants would improve swimming and boating conditions (Schroeder & Fulton, 2013). This is a prime example of how conservation efforts can be improved. Many people do not like swimming in weeds but their perception of the importance of the weeds might be altered with a more thorough understanding of the role it plays in the lakes ecosystem. It might not lead to them leaving all of the weeds along their shoreline untouched, but the consideration to remove fewer weeds for aquatic habitat is an environmental educational success. For example, a property owner who enjoys fishing might lean towards leaving the native vegetation knowing it provides optimal fishing opportunity right off of his dock. This habitat would be disturbed and probably decrease catch rates by removing the native habitat. The main goal of any environmental education campaign is to enlighten

and nourish a stewardship between humans and the natural environment that is loved and enjoyed by all.

Hopefully as everyone begins to realize the value in the land and water right in front of us, a change in societal views on protecting that land and wildlife will begin. Sometimes it might seem like human impact is destroying the Earth, but not all hope is lost. There is always something that can be done. Another study was conducted throughout Minnesota on twenty-two urban lakeshore restoration projects. If restoration is taking place, it means someone somewhere decided that an ecosystem or habitat needed help returning it to its original state. Whether or not humans were the direct or indirect driving factor causing the degradation of the habitat in the first place does not matter. Disturbance can be found all over the world due to natural and non-natural events on a regular basis. Lakeshore restoration is increasingly pursued to mitigate the consequences of housing and recreational lakeshore development (Vanderbosch & Galatowitsch, 2010). After realizing the degradation that can be caused to the shorelines by removing aquatic macrophytes, restoration projects have sprung up to help conserve those habitats. So far it has shown that the restoration of the riparian upland, shoreline, and adjacent shallow water is still an uncertain practice with high failure rates (Vanderbosch & Galatowitsch, 2010). Reviewing restoration projects pose other challenges in analysis because they typically are assessed on the scale of if the project plan was implemented as directed or not, rather than if the desired site conditions were achieved (Vanderbosch & Galatowitsch, 2010). These projects involved planting native seeds in the aquatic, upland, and transition zones of restored sites. At least some of the planted species established in all of the transition and upland sites, however no aquatic

planted species established in 27% of the restoration sites (Vanderbosch & Galatowitsch, 2010). The need for further research on urban lakeshore restoration projects and success is prevalent in Minnesota.

Lastly, I reviewed a research project conducted about the Boundary Waters Canoe Area Wilderness (BWCAW) located in Superior National Forest in Northern MN. In the 1960s a societal decision to protect over nine million acres of land and water for its wilderness character reflected U.S. wealth in natural resources, pride in the nation's cultural history, and our commitment to the wellbeing of future generations to experience wild nature and enjoy the benefits flowing from these natural ecosystems (Watson, 2011). These are the decisions and reasons there are still National and State Forests today for everyone to explore. As society has shifted its priorities, environmentalists have observed a change in visitors to these naturally preserved landscapes, sites like the BWCAW and National Parks. Since 1969, a notably different crowd of explorers visits the BWCAC, mostly much older, more experienced and better-educated population, almost exclusively white and predominantly male (Watson, 2011). The question remains what is causing these societal shifts and how can environmental education steward to these new patterns? The dependence the human population has on ecosystem services may lead to emphasized wilderness protection and conservation efforts in the future. This fact might attract the young, inexperienced, and uneducated population back to the wilderness to explore again someday. Until then, environmental educators must fight for the conservation of wilderness areas and encourage environmentally conscious use of natural resources until the importance is recognized communally.

Conclusion

The goal must be at the very least, to try to change the perception, attitude, and behaviors of society to benefit the environment. As the literature and research I reviewed concluded to show, AIS pose many problems to aquatic ecosystems around the world. They alter food webs, nutrient flow through the ecosystem, and even the characteristics of the habitat. They can outcompete and prey on native species sometimes driving them to extinction. Sadly, human vectors transfer most AIS. However, the fact that humans play such a large role in the spread and transportation of these invasive species means we can justifiably have as large or a larger impact in reducing the spread of those species. It just might take a little bit more convincing. This research has shown me in the Midwest region, and Minnesota specifically, the AIS I will focus my research on are carp, Eurasian watermilfoil, and zebra mussels. It is also apparent that campaigns and environmental education on AIS have the ability to reach some of the biggest human vectors, who are water recreationalists and in trade hobbyists. Previous research has shown a positive correlation between AIS education campaigns and the everyday users who come in contact with these species to be more willing to take the extra preventative measures from spreading the AIS.

It seems by exposing children to early childhood environmental education it can change their relationship with nature and perspective later on in life. Imagine the difference between seeing a grizzly bear in the Alaskan wilderness, viewing one at a zoo, playing a computer game with grizzly bears, or watching a cartoon bear on TV. Each one becomes less authentic and teaches the child a little less about that experience (Oltman, 2002). Real life authentic experiences have endless learning opportunities that then can

be extended in the classroom (Oltman, 2002). Educators must give the students the opportunity to catch a fish at a pond before teaching them about fish in the classroom. Children, as concrete thinkers, learn more from real world experiences that help them learn about their immediate lives (Oltman, 2002.). If educators can enhance the early stages of their lives with environmental education, the students will feel connected with nature later on in life. This will lead to environmentally active and engaged adults.

Throughout all of the research I have reviewed thus far I think it is clear that AIS education and campaigns have the ability to change attitudes and behaviors of the people who come in contact with AIS the most. The target audiences of these campaigns have the power to make a direct impact on improving preventative AIS measures, compared to someone who does not own a boat or spend time in contact with these AIS. Collecting data for my action research capstone will follow this literature review on environmental education, AIS, and conservation. In the next chapter I will discuss techniques used to collect my data and how I carried out my research procedures.

CHAPTER THREE

Methods

Introduction. In this chapter I will review all of the methods used to collect data pertaining to my thesis question *why is invasive species education important?* The point of this data was not to find a solution or an answer to the eradication of aquatic invasive species (AIS) in Minnesota, but to observe and analyze the impact AIS can have on Minnesota's aquatic ecosystems. This research is significant to the environmental community and pertains to water recreationalists and/or anyone that interacts with Minnesota's bodies of water. In obtaining this data, it will give other researchers and environmental educators a better idea of how introduced species that become invasive, can impact an aquatic habitat and native fish populations in the Great Lakes Region. There is a need to collect more qualitative and quantitative data on AIS to assist and provide environmental educators with the information they need to create effective AIS education programs pertaining to specific regions. Teaching the public and recreational water users can become more effective in formal and informal settings with more advanced AIS research and data. These projects would hopefully yield positive responses from the public to encourage engagement in minimizing the spread of the AIS in Minnesota.

In this chapter I discuss the concepts applicable to my action research methods. I will describe my research design using mixed methods, the data collection techniques used by the MN DNR Fisheries Area, permission of approval to use data collected by the MN DNR, and the setting this data was collected in.

Research Design

I am conducting an action research project about Minnesota native fish populations and the impact AIS can have on them. Pine says, "Action research takes place in a context of discovery and invention as opposed to a context of verification" (2009, p. 236). This research used a mixed methods approach as it contained qualitative and quantitative data. This research project used explanatory sequential mixed methods, which is defined as the researcher collecting quantitative data first and analyzing those results, and then further explaining the results in more detail using qualitative research (Creswell, 2014).

The quantitative data I collected was in the form of population size estimates of the species surveyed in each lake. Quantitative research is an approach used to test theories and relationships among variables (Creswell, 2014), in this case the variables being compared are the presence of AIS and native fish species population sizes. The native fish population is the variable that can be measured and is numerical data that can be analyzed using statistical procedures (Creswell, 2014). After collecting the quantitative data, I further analyzed the results using qualitative research. The research included comparing presence of AIS through historical records of lakes and the variation in native species populations in each lake. This allowed me to explore connections between the presence and invasion of AIS and how that impacts the native fish populations. The process of this research involves emerging questions and procedures, data typically collected in a natural setting (instead of in a controlled lab experiment), collection of open-ended data, representation of information in figures and tables, and personal interpretation of all findings (Creswell, 2014). I chose to evaluate my data using

the qualitative and quantitative approach to obtain the most accurate evaluation and further understand the problem being investigated. The core assumption of mixed methods is that it provides a more complete analysis than either one process alone (Creswell, 2014).

Setting. As a Fisheries Intern with the Minnesota Department of Natural Resources (MN DNR), I participated in numerous lake population surveys throughout the East Metro area of the Twin Cities in Minnesota. The East Metro Fisheries Area office is made up of eight full time and one part time employee responsible for managing 90 fishing lakes and 146 miles of rivers and streams in Minnesota (DNR, 2018). The Fisheries team and I conducted lake population surveys from May 2018-August 2018 to analyze species populations in each lake. Lake surveys were conducted daily and multiple times a week for the duration of May 2018-August 2018. The following lakes were surveyed in the 2018 summer season: White Bear, Rogers, Golden, Elmo, Demontreville, Clear, Bone, Owasso, Bald Eagle, Big Marine, Rebecca, and Spring. Regarding each one of these lakes, we recorded if there were AIS present and what species it was. AIS were recorded regardless if they were plant or animal invasive species. We also took note of any connecting water borders of each lake because this would allow the transfer of species very easily and be considered invested water. The survey techniques included gill netting, trap netting, seining, and electrofishing. All of these methods vary slightly and are useful in surveying specific species of fish to analyze their populations and collect data. Along with habitat surveys, long term monitoring involving population assessments, invasive carp and river monitoring, and Index of Biological Integrity surveys, we also performed daily fisheries management of hatchery

production and stocking the lakes. The standard lake survey information and data is made public on the DNR website by the following spring, which many anglers use as a reference. Historical records from the DNR of these same surveys were also analyzed to see if there was a correlation between species populations and the presence or initial establishment of AIS.

Variables. The research I conducted during the summer of 2018 had a number of variables at play during data collection. Adverse weather conditions can hinder team effectiveness to collect accurate data and cause human error in extreme heat, wind, or rain. Equipment failure can cause inaccurate results involving our motorboats, breaks/tears in nets, and technical problems with the electrofishing equipment. Other variables include human interaction with these bodies of water that may or may not impact fish populations. It is not possible to monitor every single lake at all hours of the day and night, so the DNR does not have control over the general public and the behaviors they chose to do at our designated research sites. For example, releasing fish into a new body of water they caught from a different lake. Sample size and variety in fish species was also a variable since it almost statistically impossible to try to account for every individual fish in the lake, these surveys provided us with an informative estimate to compare to the previous survey. AIS populations are another variable presently being considered that may impact the native fish populations.

Fisheries Survey Techniques

Each one of the techniques mentioned aided us in our lake fish population surveys conducted to monitor and assess the suitable aquatic habitat in each lake. The variety in technique and methods used allows the DNR to collect the most accurate data possible

for a wide variety of species found in Minnesota's water. In addition to this information provided online after analysis for the general public and angler use, it is referenced for MN DNR fisheries stocking management in the future.

Normal range is a term designated by the DNR to refer to the range of values for net catches or average fish size that could be considered normal for the respective lake class that the survey belongs to (Minnesota Department of Natural Resources, 2018). All of the surveyed lakes throughout Minnesota have been categorized into 43 lake classes, or groups based on chemical and physical characteristic similarities (MN DNR, 2018). Historically, the DNR used a statewide net catch average as the standard comparison of measurement for statistical current net catches. However, this method is no longer used because it is not logical to lump lakes like Mille Lacs and Lake of Woods with shallow prairie lakes (DNR, 2018). The current process and technique allows for a more meaningful comparison of similar groups of lakes. This kind of comparison prevents the conundrum of comparing apples to oranges. Otherwise you might end up missing obvious outliers that do not stand out due to the wide range of aquatic environments being analyzed together.

Catches per unit effort (CPUE) is another term for "number of fish caught", which represents the average number of fish caught per net that was set (DNR, 2018). This is the unit of measurement I used to evaluate native fish populations, which is commonly used for fisheries management practice. All catches are reported separately by gear type (gill net, trap net, electrofishing) due to their variance. All of the data collected from the following survey techniques described were recorded electronically on a tablet while in

the field or recorded using pencil and paper and manually entered into the DNR Fisheries Survey Module online system after returning from the field.

Gill netting. This is the primary technique used to survey and sample walleye, northern pike, yellow perch, cisco, whitefish, salmon, and trout (DNR, 2018). The standard size of the gill nets we used were six feet tall by 250 feet long with five different panels of mesh sizes. The number of gill nets set in a lake depends largely on the acreage of the lake (DNR, 2018). Each individual panel of the gill net is fifty feet long and mesh sizes, in inches, are as follows: 0.75, 1.0, 1.25, 1.5, 2.0. We set most of our gill nets in water offshore, deeper than ten feet and fished them for twenty-four hours. This means we set the gill net out in the morning and returned the next morning (twenty-four hours later) to collect our data. Fish are captured in gill nets by swimming into them and becoming entangled (DNR, 2018). Most fish taken in a gill net are killed, however only a small portion of the lakes fish population is taken in each individual survey event (DNR, 2018). We also detangle, collect data, and then immediately release any fish that are still alive from our gill nets. We set 62 gillnets out in the summer season surveying the lakes previously listed. Once the nets were collected we worked to record the length of each fish, determined the sex, looked for parasites or signs of disease, and remove otoliths from target species to age the fish. I assisted in the data collection in the field of 2018 and used historical records of gill net sets to analyze walleye, northern pike, and yellow perch populations in my project. The data was analyzed from gill nets because it is the most effective method of catching those specific fish species and has been standardized since the earliest MN DNR Fisheries records. There was no variance in the methods used in the

field to collect my data in 2018 from the gill nets set throughout MN DNR Fisheries history.

Figure 1. 250 foot long gill net. The black line on top is held up with floats and the bottom blue line is lead line, causing it to sink and sit in the water as pictured above. Set at the target depth per lake. Due to the fine mesh netting, fish do not see it, swim into it, and end up entangled.

Trap netting. This method is primarily used to survey crappie, bluegill, and bullheads (DNR, 2018). The standardized trap net we used are four feet tall by six feet wide with a forty foot lead and were primarily set perpendicular to shore in water less than eight feet deep. The fish are caught by swimming into the lead and following it

towards the trap (DNR, 2018). The mesh of the trap nets is small enough that most fish do not become entangled. We set a total of 96 trap nets out this summer in the lakes previously listed. After setting the trap net for twenty-four hours we would return to collect our fish samples. We would haul the trap net up onto our boat, dumping the contents into a large bucket filled with water (because most species found in a trap net are alive) and then collect our data. After measuring the fish in length (mm) the fish would be returned to the lake.

Figure 2. Standard trap net. Fish swim along the shoreline and swim into the forty-foot lead line, which guides them to pass through the frame and swim into the hoops where they cannot escape.

Electrofishing. This is a special piece of equipment commonly used to sample largemouth bass, smallmouth bass, and young of the year walleye (DNR, 2018). A boat-mounted generator is used to induce electrical current into the water and temporarily stun

the fish, allowing fisheries workers to net the fish (DNR, 2018). After netting the fish, we would place them in a large tub with water and oxygen until we collected the necessary biological data. We measured and recorded length for each fish. Most fish recovered rapidly from the electrofishing experience and were returned to the same body of water. Bass are an extremely visually oriented fish, so they do not get caught in the other nets we set like trap nets and gill nets. This obstacle has caused us to rely on nighttime electrofishing methods to study the local bass populations. Due to their visual strength, these surveys must be conducted in the dark to prevent them from swimming away and skewing data results. I participated in an electrofishing survey of largemouth bass on Turtle Lake after sunset, around 9 pm until 1:30 am. We also commonly used the backpack electrofishing method for surveying the shoreline, which was required during the index of biological integrity surveys. This involved the same methods as described above on a smaller scale. By wading through the water wearing proper protective gear and sending small electrical currents into the water using the anode probe, netting the stunned fish, and placing them in the bucket with water to bring back to the boat to collect data. This method typically sampled small shoreline species like green sunfish, darters, minnows, and shiners. These species were not chosen as target species for my project due to the electrofishing method necessary to survey them.

Seining. This is the process of catching fish with a seine net. Trawls and shoreline seines are usually small meshed nets used to catch young fish (World Fisheries Trust, 2008). Seine nets have floats along the top and a lead line at the bottom (World Fisheries Trust, 2008). This technique typically encircles a school of fish and then concentrates them into a small area by pulling in the sides of the net (World Fisheries Trust, 2008).

This method required one person on each side of the net as we pulled it in to make sure fish were not swimming out. We hauled the bag of the seine net completely onto our boat into a bucket of water to collect the fish out of the net. This technique was primarily used during index of biological integrity surveys, which differ from the standardized lake surveys.

Figure 3. 50 foot seine net can be dragged along the shoreline to sample species diversity.

By-catch. We did have numerous species caught in our nets that we did not intend on studying. Snapping turtles, painted turtles, and soft shell turtles were primarily found in the trap nets. Data was collected from these species, such as a carapace length for snapping turtles, total number in bulk for the other species, and then returned to the lake. Muskrats and crayfish were also caught on occasion. These species did not require any data collection and were returned to the lake immediately. Unless a rusty crayfish was identified, which is an invasive species, it would not have been returned to the lake. There were no rusty crayfish caught during our surveys.

Index of biological integrity. An index of biological integrity (IBI) is a score that compares types and numbers of fish or plant species observed in a lake as to what is expected in a healthy lake (DNR, 2018). One measure of a lake's health depends on the community of fish, plants, and aquatic life it can support (DNR, 2018). Certain species found in Minnesota's lakes need clear water to survive and healthy habitat, while others have success in degraded conditions. These specific species are considered "indicators" of the health of the lake (DNR, 2018). I assisted the DNR in IBI assessments using gills nets, trap nets, seines, and electrofishing methods. The fish based IBI assessments place lakes in one of five designations: exceptional, fully supporting, vulnerable, not supporting, and insufficient information (DNR, 2018). The data collected from the IBI surveys were not used in my analysis because these methods do not fit into the historic standardized lake survey methods.

Components of Research

Historical records. I reviewed and compared the historical records of previous lake population surveys conducted by the MN DNR Fisheries Area from as early back as 1948, to present day including the data we collected in the field this past summer in 2018. I analyzed the fish populations by species and by individual lakes to see if any patterns had developed in the past 70 years from gill net results. I also referenced the Infested Waters list created and provided online by the MN DNR for the public to reference the establishment, presence, and spread of AIS throughout the lakes we surveyed. This was done to see if there were any correlations between AIS populations and native fish species populations. These results were compiled to represent qualitative data that helped

me interpret the impact AIS presence and establishment can have on native fish specie and their populations.

Permission. I received verbal permission from the MN DNR to participate in the collection of this data for use in completing my Masters Degree in Natural Science and Environmental Education for Hamline University. I met with the East Metro Fisheries Area Supervisor to discuss and describe the details of this project, what the data will be used for, and that this capstone thesis will remain archived in a public library after my submission is accepted. These actions were approved by my supervisor from the East Metro Fisheries Office of the MN DNR to use in fulfillment of my capstone thesis.

Conclusion

As a Fisheries Intern for the MN DNR, I assisted in conducting fish population surveys throughout Minnesota lakes found in the East Metro territory that includes Anoka, Ramsey, Washington, and Dakota counties. To obtain the most accurate data we used a variety of methods such as trap nets, gills nets, seining and electrofishing techniques to assess native fish population species found in the lakes. I also obtained historical records of these standardized lake surveys and AIS populations to analyze. In the next chapter, I will review the data collected from the field season May 2018- August 2018 and DNR historic records from the previous seventy years. This will help my investigation for the necessity for AIS education in Minnesota. It will allow me to analyze how AIS affect native fish populations and lake health, how humans interact with these species, and possible AIS education methods that would be beneficial for use in preventing the spread of AIS in Minnesota.

CHAPTER FOUR

Results

The point of answering my thesis question, *why is invasive species education important*, is to help improve our future environmental education efforts on the topic of aquatic invasive species in Minnesota. To do so, we need to know as much as possible about these invasive species and how they impact our native species. The goal of this research project was not to evaluate current AIS education plans and campaigns, rather analyze data that relates to these issues to provide further support in the debate on the necessity of AIS educational campaigns. In this chapter I will analyze my data and interpret the results of my action research pertaining to aquatic invasive species (AIS) impact on native Minnesota fish populations.

Overview of research. The three fish species analyzed in my project were walleye (WAE), northern pike (NOP), and yellow perch (YEP). These three species were chosen because they are target species for gill netting equipment, which falls into the standardized surveys dating back to the 1950s. The MN DNR Fisheries Area is in charge of managing 4,500 lakes and 16,000 miles of fishable rivers and streams that allow you to enjoy quality fishing and pristine aquatic habitat throughout Minnesota. Part of this management involves running hatcheries and the stocking of specific fish species, such as: walleye, trout, muskellunge, and a few others. These stocking procedures assisted me in choosing my target species for population dynamic research. Most species are stocked to combat heavy fishing pressure. I wanted to compare species that are naturally reproducing, like the northern pike and yellow perch, to a species with stocking management regulations like walleye. Out of the standard surveys that were conducted on

twelve lakes throughout Dakota, Ramsey, Washington, and Anoka counties, Rogers Lake and Spring Lake were not included in my data analysis due to a lack of historic data. The historic surveys did not provide me with adequate data to analyze fish population's pre and post AIS establishment, so they were omitted from my results.

I grouped my data sets to be analyzed by AIS presence. It is most valuable to evaluate each set of lake data based on the AIS that are present. First, I will review data from Golden Lake, representing a lake without any AIS present. Next, I will evaluate lakes that are invaded by Eurasian watermilfoil. Then I will analyze lakes infested with zebra mussels and finally conclude with lakes that have multiple invasive species present. This will allow similar settings to be compared against one another to observe trends and relationships between the AIS and population dynamics of northern pike, yellow perch, and walleye.

Typically there is a baseline or control group in many action research projects. In this case, when working with bodies of water and fish population dynamics, it can be a bit more challenging because every body of water is unique to its own properties such as size, water quality, depth, vegetation, etc. Due to these challenges, the CPUE rates in a lake without AIS do not technically serve as a control group in this action research project. Another reason a lake without AIS cannot be considered a control group is because the anthropogenic impact on it is unknown. Therefore, the real comparison and observations are made from the before and after CPUE rates of the establishment of an AIS in each lake. However like with most ecological studies, it is best to compare population dynamics over long periods of time. This must be considered when evaluating

graphs and data sets from the latest invasion of AIS on the surveyed lakes and how long that ecosystem has had to respond to the new invasion.

Data Analysis

Assessing population dynamics within fish stocks can be a challenging task. The accuracy in many methods is controversial throughout fisheries management due to the fact that their natural habitat is not easily accessible or easily observed. However, size structure and catch per unit effort (CPUE) are commonly used by fisheries managers to draw inferences about fish population dynamics (Brooks, 2012). Since I chose to use the mixed methods style of research collecting quantitative and qualitative data some data is numerical and some is not. The variables present in this research project were three different species of native fish catch per unit effort rates (in numerical value) and the observation of the presence or absence of aquatic invasive species in each lake. The data graphed below was computed from catch-per-unit-effort (CPUE) rates from fish samples conducted during standard lake surveys.

A C/ f index is defined mathematically as C/ $f = qN$, where C is the number of fish caught, f is the unit of effort expended, q is the catch ability coefficient or probability of catching an individual fish in one unit effort, and N is the absolute abundance of fish in a stock (Fabrizio & Hubert, 2007). When numerical abundance cannot be estimated, fisheries scientists often use C/f to make judgments about the abundance of fish in a stock (Fabrizio & Hubert, 2007), which is the method I chose to apply to analyze my data. Due to the large quantity of data that was collected and analyzed I chose to categorize the lakes by AIS infestation. The following categories will be analyzed in this order: lakes

without any AIS, lakes with Eurasian watermilfoil, lakes with zebra mussels, and lakes with multiple AIS.

No AIS present. The only lake surveyed in the 2018 field season without any AIS present was Golden Lake.

Golden Lake is a 57 acre lake in Anoka county with a maximum depth of 25 feet. Walleye were first stocked in Golden Lake in 1985 and 1986, then suspended until 2001 and stocked biennially, every odd year since.

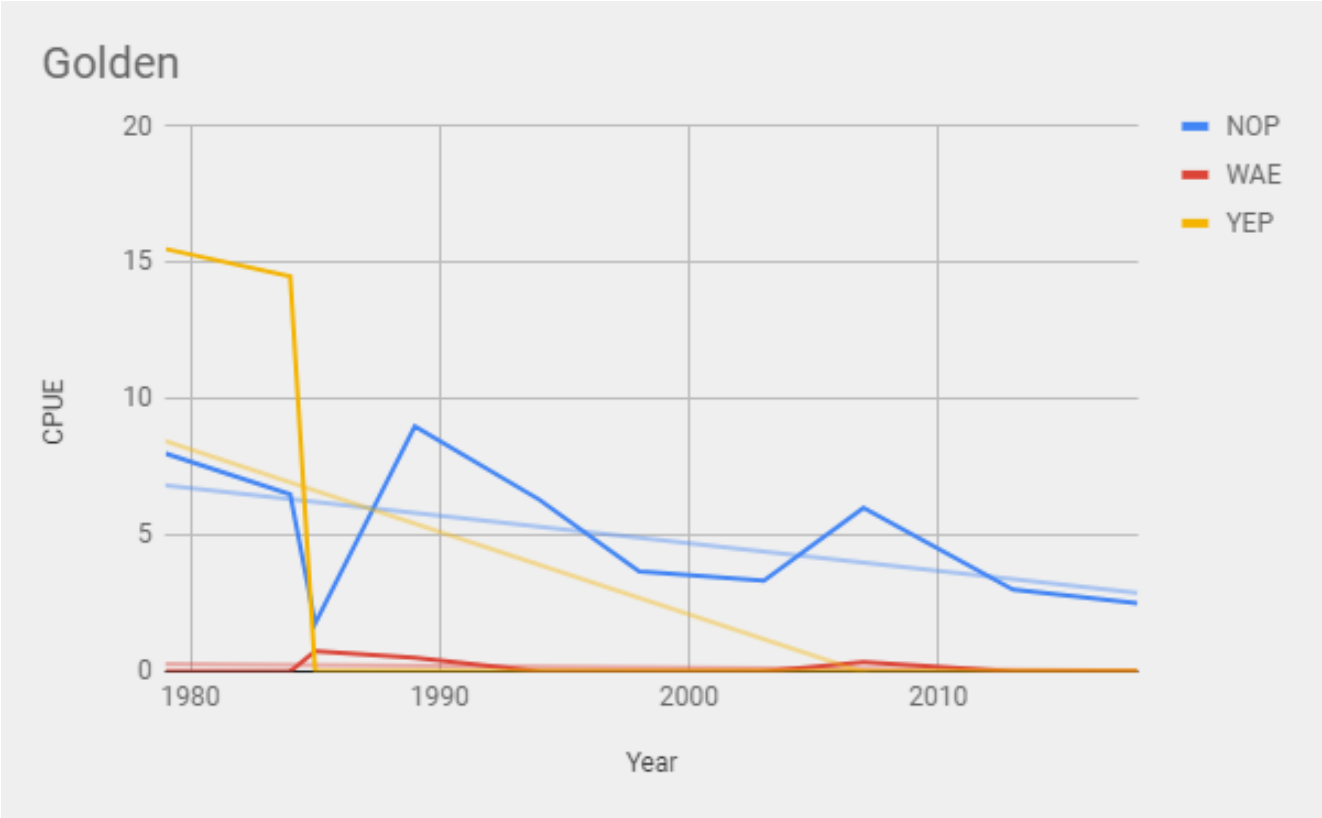

Figure 4. Golden Lake currently has zero aquatic invasive species present. Two gillnets were set for 24 hours on Golden Lake in May 2018. There is an obvious decline in all three species observed in the past 30 years, unrelated to any AIS. The CPUE results were as follows:

Year	NOP	WAE	YEP
2013	3	0	0
2018	2.5	0	0

Table 1. There was a decrease observed in CPUE rates from the last survey conducted on Golden Lake in 2013 in northern pike, while walleye and yellow perch remained stagnant due to their minimal CPUE rates. A CPUE rate of zero does not mean there are absolutely no more walleye or yellow perch left in Golden Lake, it simply means they are becoming increasingly scare.

Eurasian watermilfoil. Eight of the ten lakes included in this summer survey were infested with Eurasian watermilfoil (EWM). This is a highly abundant aquatic invasive plant species found throughout the Metro area of the Twin Cities. The patterns observed in the relationship between the establishment of this aquatic plant and the fish CPUE rates will be able to lead to better education and management efforts determined by the impact this AIS has. The window of initial establishment of EWM of the eight lakes surveyed range from 1995-2008. The lakes infested with EWM from my survey include Elmo, Clear, Bone, Big Marine, Demontreville, Owasso, White Bear, and Bald Eagle. Instead of including an excess amount of data, the selected graphs below are representative of similar results found in all the lakes surveyed with EWM. The other three lakes infested with EWM can be found in Appendix A. White Bear and Bald Eagle have additional infestations and will be represented in the category with multiple AIS.

Owasso Lake is a eutrophic lake found in Ramsey County. It is 384 acres and maximum depth is 37 feet. Walleye stocking was conducted biennially in even numbered years until 2017 when annual stocking began.

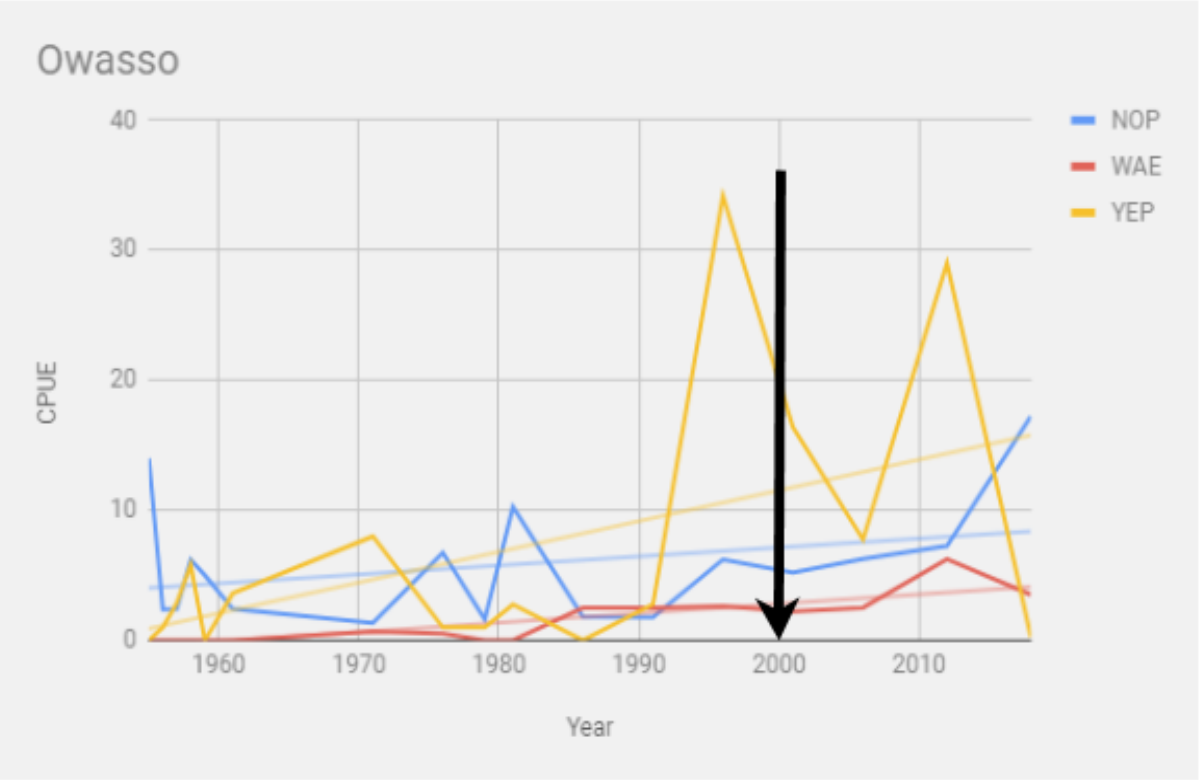

Figure 5. Owasso Lake became infested with EWM in 2000, which is represented by the black arrow. Four gillnets were set for 24 hours on Owasso Lake in June 2018. There were major fluctuations observed in yellow perch populations following the establishment of EWM in Owasso Lake. However, trend lines still indicate increasing populations for all three species. The CPUE results were as follows:

Year	NOP	WAE	YEP
2012	7.25	6.25	29
2018	17.25	3.5	0.25

Table 2. There was a major decrease observed in walleye and yellow perch CPUE rates, even though their trend lines depict otherwise. There was a significant increase in northern pike rates based on a comparison from the last survey.

Big Marine Lake is 1,756 acres and found in Washington County with a maximum depth of 60 feet. Walleye stocking was conducted biennially in even numbered years until 2017 when annual stocking began.

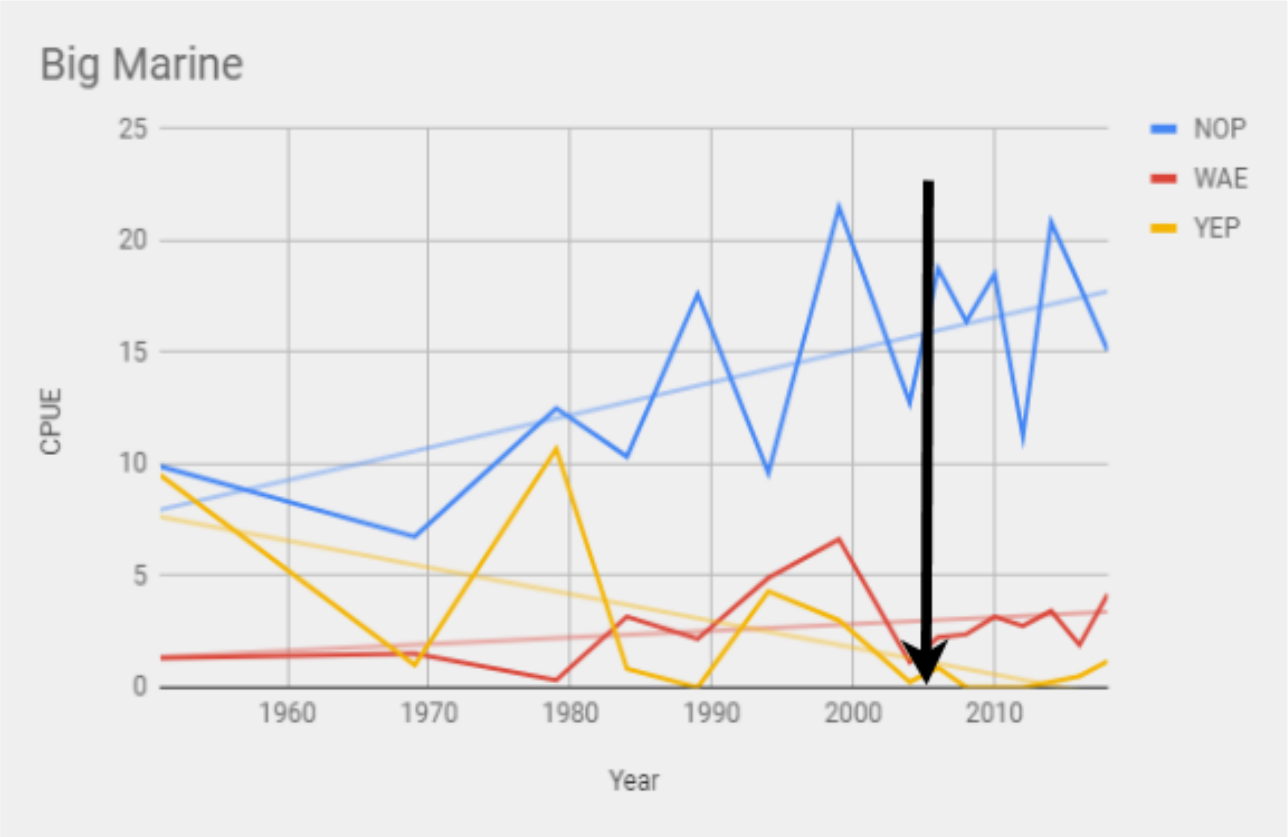

Figure 6. Big Marine Lake became infested with EWM in 2005, represented by the black arrow. Twelve gillnets were set for 24 hours on Big Marine Lake in August 2018. Northern pike populations seem to fluctuate following the infestation of EWM, but still have an increasing population trend line. Yellow perch are represented by a declining trend line, but seem to be increasing within the past five years. Even though walleye populations seem to fluctuate, their trend line appears to be stable at low CPUE rates possibly due to increased stocking efforts. The CPUE results were as follows:

Year	NOP	WAE	YEP

2016	18	1.9	0.5
2018	15.05	4.17	1.17

Table 3. There were small increases observed in CPUE rates for walleye and yellow perch in the comparison of the last survey. There were fluctuations in northern pike populations, represented by a slight decrease in CPUE rates even though their trend lines is increasing.

The last lake to be reviewed with EWM is Clear Lake. Clear Lake is 434 acres with a maximum depth of 28 feet and located in Washington County. Clear Lake is currently being stocked with walleye annually.

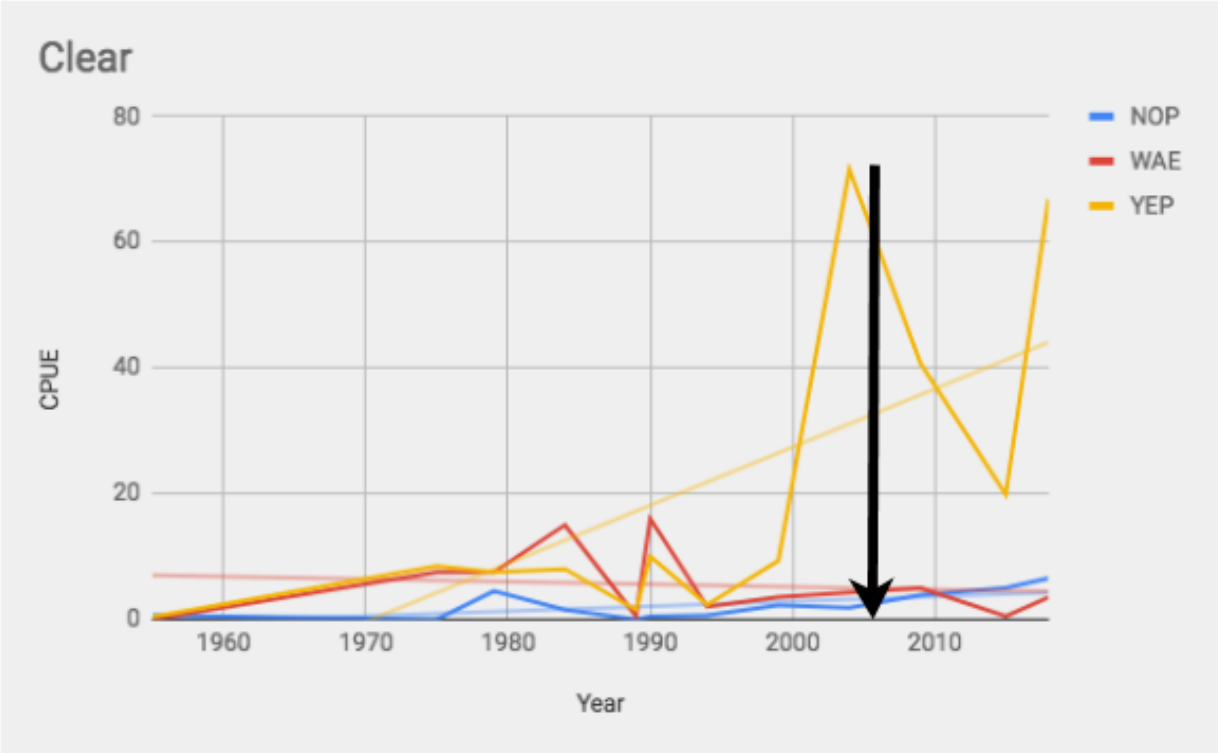

Figure 7. Clear Lake became infested with EWM in 2006, represented by the black arrow. Four gillnets were set for 24 hours on Clear Lake in June 2018. A dramatic decline in yellow perch populations is observed around the time EWM becomes established in

Clear Lake. Even though northern pike and walleye appear to fluctuate slightly following the EWM invasion, stable trend lines that are increasing at very slow rates represent them both. The CPUE results were as follows:

Year	NOP	WAE	YEP
2015	5	0.5	19.83
2018	6.5	3.5	66.83

Table 4. The CPUE rates of all three species represent increasing populations following the latest survey comparison. Even though fluctuations are observed with some declines following the EWM invasion, the trend lines and latest CPUE rates display increasing populations of all three species.

Zebra mussels. Only two of the ten lakes surveyed were infested with zebra mussels (ZM). This includes White Bear Lake and Rebecca Lake. Zebra mussels are a species of small freshwater mussel that has established invasive populations throughout the Great Lakes Region. This data will help depict how these freshwater mussels impact and interact with the fish populations in Minnesota, which will lead to more effective education and management of the lakes that already have established populations. Rebecca Lake is considered infested due to its connection to the Mississippi River during high water and flooding periods.

Lake Rebecca covers 77.3 acres in Dakota County with a maximum depth of 15 feet. It is located in the floodplain of the Mississippi River. Walleye have not been stocked in Lake Rebecca since the lake was reclaimed in 1997, however walleye (and many other species) migrated into the lake when the Mississippi River flooded in the spring of 2001.

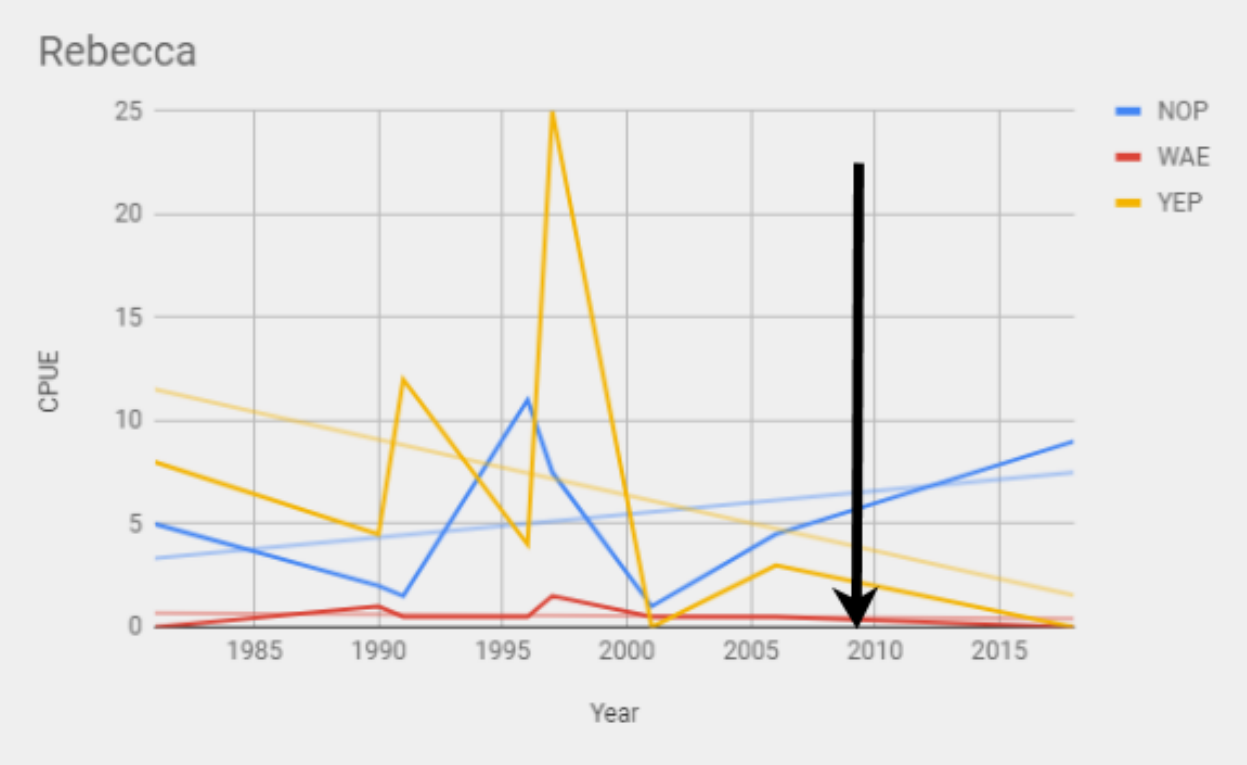

Figure 8. Lake Rebecca was infested with zebra mussels in 2009, represented by the black arrow. Two gillnets were set for 24 hours on Lake Rebecca in August 2018. Following the infestation northern pike populations seem to be increasing, while yellow perch populations seem to be declining. The CPUE results were as follows:

Year	NOP	WAE	YEP
2006	4.5	0.5	3
2018	9	0	0

Table 5. There was a large gap in years Lake Rebecca was surveyed. The CPUE results indicate the increasing northern pike populations and declining yellow perch population. Walleye do not have a strong presence in Lake Rebecca.

Multiple AIS. There were two out of ten lakes surveyed with multiple AIS present. Bald Eagle Lake has established populations of EWM and flowering rush, which

are both aquatic invasive plant species. Flowering rush is a reed like plant with pink flowers that can grow densely along shorelines making water access challenging (DNR, 2018). It also can outcompete native plant species, which could lower species diversity (DNR, 2018). I decided to evaluate lakes with multiple AIS in the same category to compare how establishment of AIS populations play a role in CPUE rates of fish when other AIS are already present. This evaluation could be helpful to environmental education by increasing awareness of lakes that have single AIS present and efforts in preventing secondary and tertiary AIS from invasion by showing repercussions of multiple invasions. Moving forward with this data analysis is helpful to show how fish populations change due to secondary invasions of different AIS. This is a complex topic to study due to the multiple independent variables at play. This may lead to confusion in assessing which independent variable (AIS) impacts the dependent variable (CPUE rates) the most. White Bear Lake has established populations of EWM and zebra mussels. Both lakes had multiple AIS establish between 1995-2014.

Bald Eagle Lake is a eutrophic lake covering 1,268 acres in Ramsey and Washington County. It has a maximum depth of 36 feet. From 1998 until 2017, walleye had been stocked biennially in odd numbered years. Since 2017 walleye have been stocked annually in Bald Eagle Lake.

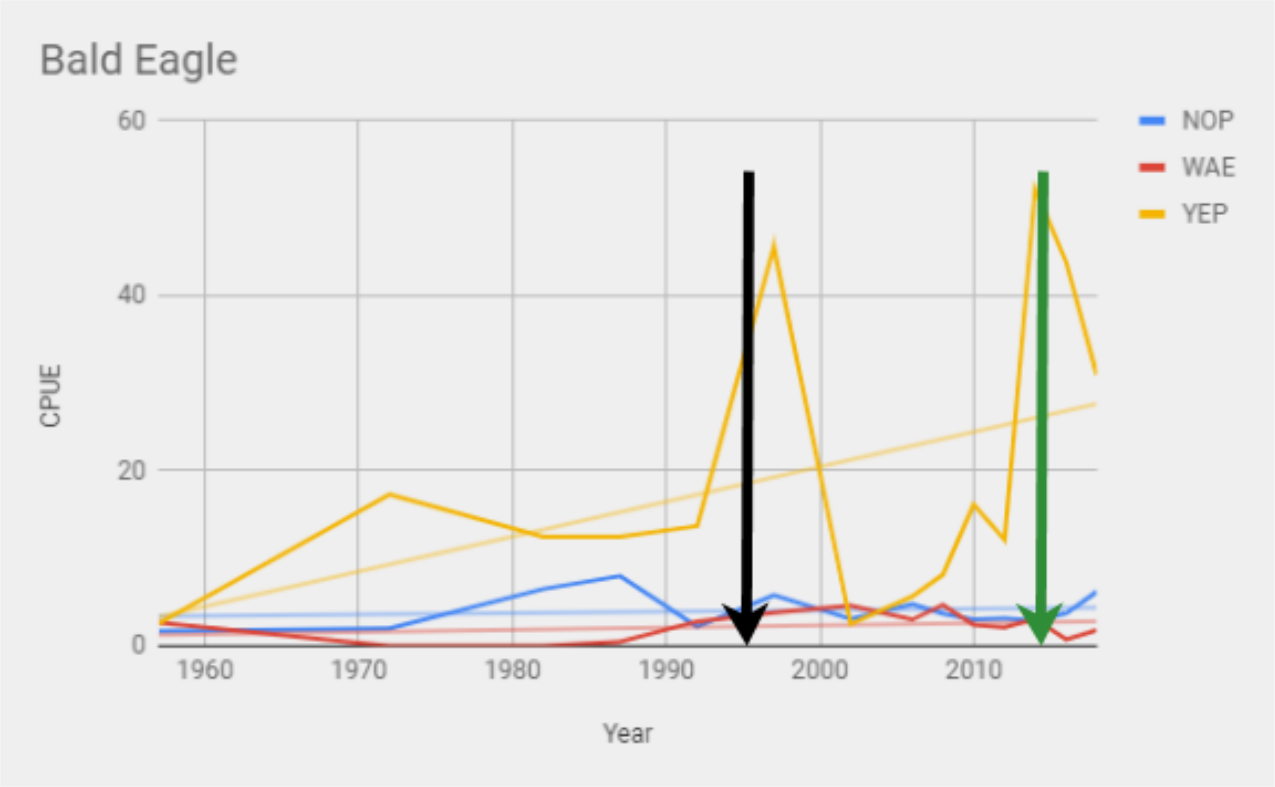

Figure 9. Bald Eagle Lake became infested with EWM in 1995, labeled with the first black arrow. The lake became infested with a secondary aquatic plant invasive species, flowering rush, in 2014 represented by the green arrow. Ten gillnets were set on Bald Eagle Lake in July 2018. Major fluctuations were observed after the EWM establishment and seem to be crashing again after the establishment of flowering rush. Northern pike and walleye trend lines seem to represent stable populations at a very low density. The CPUE results were as follows:

Year	NOP	WAE	YEP
2016	3.75	0.75	43.83
2018	6.2	1.8	31

Table 6. Even though northern pike and walleye trend lines appear to be stable, a slight increase in CPUE rates were observed compared to the previous survey. Yellow perch populations seem to be declining after peaking prior to the flowering rush infestation, even though their trend line remains increasing.

White Bear Lake is a mesotrophic lake found in Ramsey and Washington County. It covers 2,427 acres and has a maximum depth of 83 feet. White Bear Lake has received annual stocking of walleye since 1970.

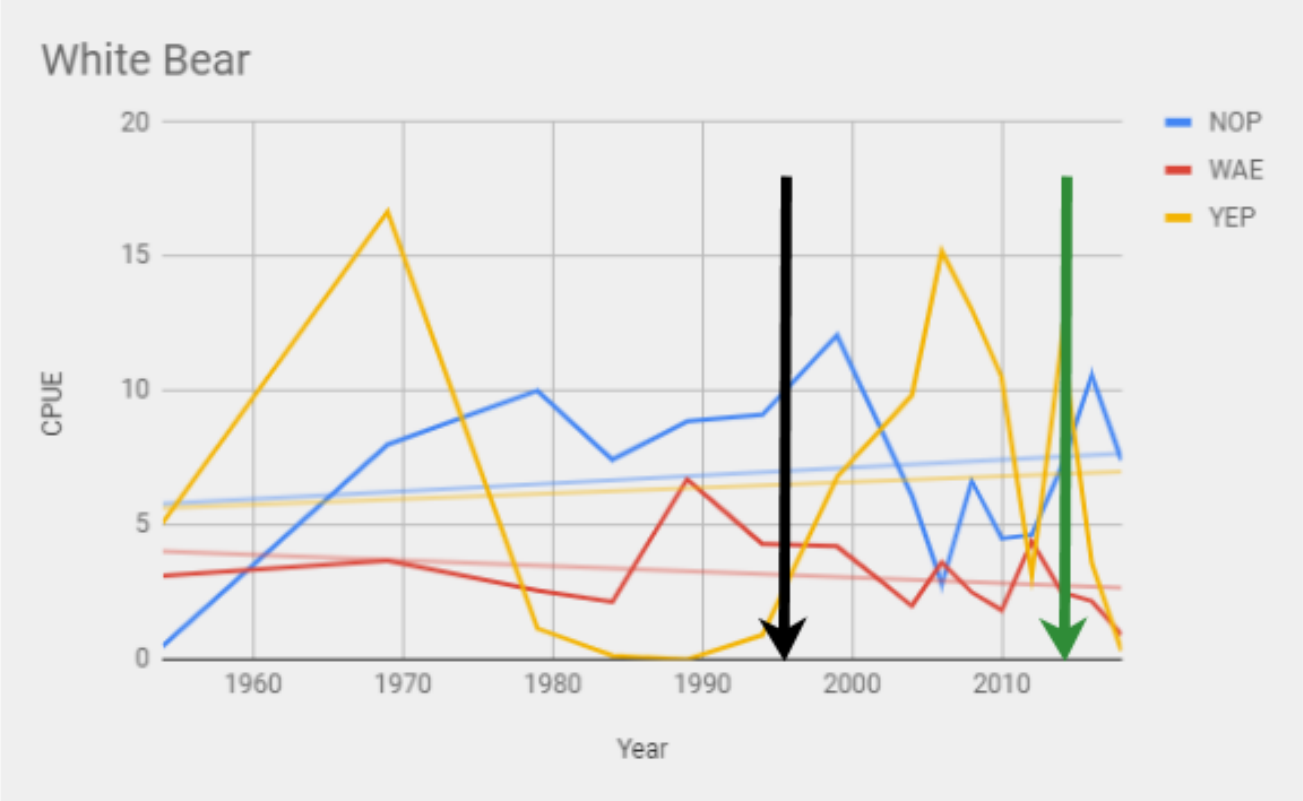

Figure 10. White Bear Lake became infested with EWM in 1995, represented by the black arrow. Zebra mussels established a population in 2014, represented by the green arrow. Twelve gillnets were set on White Bear Lake in July 2018. Fluctuations were observed in all three species after the establishment of EWM. Even though the

establishment of ZM is fairly recent, trend lines for all three species appear stable. The CPUE results were as follows:

Year	NOP	WAE	YEP
2016	10.58	2.17	3.58
2018	7.42	0.92	0.33

Table 7. The data of CPUE rates from the previous survey represents declining populations in all three species. However, the trend lines of all three species appear to reflect relatively stable populations possibly due to the lack of time between the establishment of ZM and this evaluation.

Correlations Between Fish and Aquatic Invasive Species

As previously stated each lake is unique in its own characteristics, which will lead to varied CPUE rates. For example, a decline in all three species was observed from CPUE rates in Golden Lake, which had zero AIS present. This could have been caused by any number of variables that impact fish populations. These variables could include naturally occurring events or anthropogenic impacts, such as pollution run off or fishing pressure. Even when AIS invade new bodies of water, there could be other factors at play that impact fish population dynamics not related to the presence of the AIS.

Aquatic Plant Invasive Species

While declines and fluctuations were observed in CPUE rates in many of the lakes following EWM invasions, the trend lines appeared to still represent increasing or stable populations. Themes of a declining population would be expected after an AIS invasion based on my literature review. It is assumed invasive species can cause a decline in diversity and outcompete native species. However, my results do not fully support this

opinion. This analysis is evaluating an aquatic plant species impact on fish populations, not other aquatic plants. If a survey of aquatic plant species occurred after the invasion of EWM, a decline in other aquatic plant species might be observed which would have supported my literature review. This research was evaluated as the independent variable's (the presence of AIS) relationship with the dependent variable (fish CPUE rates).

The results of my data imply that there is a decline observed in some CPUE rates, but not to an extreme extent that would cause an ecological shift in the system. This pattern opposes my literature review. Following my data analysis, I believe Eurasian watermilfoil is similar enough to northern watermilfoil that it provides fish with acceptable coverage and habitat, contrary to what most literature says. The two aquatic plant species are similar enough to have hybridized throughout water bodies in Minnesota. This leads me to think the fish in the Metro Area are not highly selective in regards to aquatic vegetation habitat. The fish cannot identify the difference between the two species of watermilfoil or the hybrid species, so when they find suitable aquatic vegetation they seem to be choosing it to use it as habitat. It seems these three fish species have adapted to this new AIS and their populations have not suffered drastically from its invasion. Again, this might be due to a strong similarity to a native aquatic plant that is already present. This is demonstrated by most of the trend lines that remain increasing for northern pike, walleye, and yellow perch even following the establishment of EWM.

Aquatic Invertebrate Invasive Species

Zebra mussels were the only aquatic invertebrate invasive species analyzed in this research project. Declining fish species populations would be anticipated after the

establishment of zebra mussels if results were in line with my literature review. For the most part, my data supports this theme. These results were expected and did not surprise me. Since the invasion of zebra mussels in White Bear Lake all three species CPUE rates have declined. This is true of Lake Rebecca's population of walleye and yellow perch following the zebra mussel invasion too. This is anticipated after a zebra mussel invasion because they filter feed the algae out of the water, which leads to a decline in zooplankton, which can be a large component of some fish species diets. The obvious analysis is that when a new species enters the food web, they dramatically decrease resources for all other species. However, the one disagreement my data reflects is an increasing population of northern pike in Lake Rebecca following the zebra mussel invasion. CPUE rates and populations may vary due to flooding events of the Mississippi River into Lake Rebecca, connecting the two bodies of water temporarily allowing other fish to swim into Lake Rebecca.

Summary. As I analyzed my data, the results became more comprehensible as I grouped the lakes by AIS. It is now clear that invasive aquatic plant species do not impact fish populations as much as invasive aquatic invertebrate species do. The reason for these results could be due to the natural competition of these invasions. The aquatic plants that are invading these lakes are not competing with fish for resources; they are competing with the other aquatic plants for sunlight to photosynthesize. This might lead to a decrease in diversity in aquatic plant species, but it does not appear to decrease native fish populations. This could be the case because it increases vegetation coverage, providing fish with more aquatic habitat that is very similar to what is naturally found

here with northern watermilfoil. This may only be the case in this scenario due to the nature of the invading plant being similar to native species that are already present.

In contrast, invasive aquatic invertebrate species impact fish populations negatively due to competition for the same resources. The main difference between the results observed from aquatic invasive plant species and aquatic invasive invertebrates are due to what they feed on. When it comes to zebra mussels, their diet is the main concern. They filter feed on phytoplankton, which is what zooplankton feed on, and many young fish are dependent on zooplankton for survival (Gunderson, 2018). Due to this direct connection to the food web of fish, a stronger negative correlation was observed between the establishment of zebra mussels and declining CPUE rates.

When analyzing lakes with multiple infestations of AIS, it seemed that the invasive species itself is the crucial connection to changing fish population dynamics, not necessarily how many different AIS are present or not. As seen in White Bear Lake, fish populations remained stable after the invasion of EWM but start to decline after the presence of zebra mussels. Bald Eagle Lake provides another example of these patterns. After the invasion of EWM fish populations remain stable with increasing trend lines, and this pattern continues even with a secondary invasion of another aquatic invasive plant species. After flowering rush is established in Bald Eagle Lake fish populations remain stable or continue with an increasing trend line. These observations might be brought to light by lakeshore development leading to a lot of aquatic vegetation removal. It seems as though the target fish species have adapted to using these invasive aquatic plant species, which may have been caused by a lack of native vegetation. Removal of aquatic vegetation is an anthropogenic impact possibly causing higher competition

between fish for suitable habitat. I believe the type of AIS is the most important factor in impacting fish populations, even though multiple infestations are problematic for any aquatic ecosystem.

Conclusion

Overall, the observations made from this data surprised me. If all of my data supported my literature review I would have observed declining fish populations by CPUE rates in every lake following the establishment of any AIS. However, something else was depicted within my data. It seems that the aquatic invasive plant species do not negatively impact fish populations as much as predicted. My assumption is that these fish species have adapted to the new vegetation and find it as suitable habitat. This would support stable populations or even increasing populations due to less competition for aquatic habitat.

I was not surprised to observe declines in fish populations due to zebra mussel's establishment. This was expected and aligns with my literature review because of direct competition for the same food sources and alterations in the food web. This drastic change can lead to fewer resources to sustain fish populations, which could cause slower growth rates, decreased reproduction, and declining population trends. Further research must be conducted to identify if fish are adapting quickly enough to these invasive vertebrates, by changing dietary habits due to decreased availability in resources.

In chapter 5 I will discuss how the data from my lake surveys is applicable to environmental education efforts related to aquatic invasive species and answering my thesis question of *why is aquatic invasive species education important*. Using data from lakes found throughout the Twin Cities metro area in Dakota, Anoka, Ramsey, and

Washington counties will provide specific examples of relationships between fish and AIS that could be used in environmental education lessons about freshwater ecology. I will reflect on the process of conducting research, collecting data, and what it has shown me thus far. The fifth chapter will discuss research limitations and further research that could be conducted on AIS throughout the Midwest.

CHAPTER FIVE

Conclusion

Introduction. My thesis question, *why is invasive species education important*, stems from my inner curiosity about ecological systems found in nature. I have always been fascinated and intrigued by it, which is what led me to pursue an education and career in this field. I chose to explore this question due to my ecocentric values. I believe an ecosystem, as a whole is more important to preserve and protect, not each individual organism in that system. This means sometimes conservation and restoration projects have to remove and or exterminate species that do not belong there, in the hopes to restore the ecosystem to what it once was. I firmly believe in this methodology, which is why invasive species should be removed and killed without ethical guilt.

In this chapter I will summarize my experience developing and completing this capstone action research project as a researcher, writer, and learner. I will revisit my literature review and discuss ways it related to the process of collecting and analyzing fish population data in correlation to AIS in Minnesota. I will also describe ways my data can be applied to environmental education efforts in Minnesota moving forward.

Learning Process of Action Research

No matter what you are studying or researching, the process is always unique. It is unique to your action research project because of how it is conducted, what data is collected, and who conducts the research. At a certain point in the process the research becomes personal and holds significant value to you. It is hard for it not to be personal when you dedicate so much time, money, and effort into something. My favorite aspect of research is that there are no definitive answers; research is in fact open ended. You

might be researching one thing when an entirely unrelated discovery presents itself that you were not even looking for.

As an ecologist I learned about new relationships between fish populations and their communities. There are numerous characteristics that are crucial to fish population dynamics, such as: water quality, vegetation, spawning habitat, climate/water temperatures, fishing pressure, runoff pollution, and many others. However as a researcher, trying to take all of the variables that impact fish populations into consideration can be very overwhelming. To make sure I could meet my goals and stay on track with my timeline, I realized not everything could be sampled and analyzed. Working within a timeframe means you must identify the most valuable characteristics of your study to focus your time on. I learned throughout this process that literature review, research, and data analysis could go on for as long or as short as you would like. I have so many unanswered questions that if pursued, would lead me on to an entirely new study. In this sense, you must control your inner scientific curiosity to complete your research before getting side tracked with other future research questions.

As a writer, I found my personal interests very motivating throughout the writing process. I had a similar experience with public speaking during my undergraduate degree. I always had an intense fear of speaking in front of people, until I began my upper level biology courses when I was tasked with giving long presentations in class. I was able to present on topics I truly cared about and interested me which made all the nerves fade away. I commonly had to cut content out of my presentations, otherwise I would go over my allotted time. This was a drastic change from a time when I did not even want to introduce myself to a crowd of people. After crossing that bridge, I realized passion and

personal interest could make a big difference in your performance. This capstone experience proved similar. I was worried and lacked confidence in my ability to produce a paper over 50 pages, but was genuinely surprised at how easily the content filled the pages. Again, I was pleased to learn that my passion and invested interest in nature and wildlife provided me with the tools I needed to find success.

As a learner, I am very thankful for this entire experience. Not only did I learn an extensive amount about fisheries management, fish population dynamics, and aquatic invasive species in Minnesota but I also learned a valuable lesson. I learned what I imagine most scientists eventually encounter in their career at some point, which is that research does not always give you the answers you are looking for and sometimes you have to accept inconclusive results. Although I learned so much throughout this research process, I have to admit it does not provide definitive answers as to how AIS can impact Minnesota fish populations. This conclusion in itself surprised me because I thought I would find results that supported my literature review very easily. This reiterated how different all research projects are, even if you are studying the same general topic. My research just barely scrapes the surface of this topic, and the more I learned about the topic, the more complex I realized the issue was. Sometimes research must be conducted for decades or centuries in regards to complex environmental issues that involve multiple variables. In present day research, we face an additional challenge that impacts every aspect of the natural environment including all plant and animal species: a changing climate. Climate change is a broad term encompassing all of the changes being observed in ecosystems around the world, largely due to anthropogenic impact. This underlying

factor has to be considered now when evaluating any ecological system due to its unknown implications.

I would not have thought this originally, but I learned that your passion plays a big role in writing your thesis. I have always had an invested interest in wildlife and the environment, which has inevitably guided me down this very path. The entire process of writing a literature review, conducting action research, and analyzing data is very strenuous and time consuming. I can proudly say I thoroughly enjoyed every minute of this process because I studied something that not only interests me, but also concerns me.

Limitations of research. I came across many factors limiting my capstone research project. Time and money can commonly be found as limitations throughout many aspects of life, which holds true to my capstone as well. If I had more time and resources I would have collected more data to provide a deeper explanation of the correlation between fish and invasive species. This data could have included age, weight, and length of all the fish sampled to see if the presence of AIS impacts fish growth rates, mean body mass, and reproductive cycles. For example, a hypothesis derived from my research and results would be to expect to see a decrease in mean body mass of fish after zebra mussels invade due to the increased competition for food sources. This could lead to different growth patterns or maturation. However, aging a fish is a time consuming process and involves removing the otolith bone from inside the head cavity and counting annular growth rings in the bone sample, which are only visible underneath a microscopic lens. I also was limited by the style of research I wanted to conduct to be able to compare it to historical records.

Since I was analyzing archived MN DNR Fisheries data I had to stay within the restrains of the standardized survey technique and methods to be able to compare and contrast my data from the 2018 field season to data collected in 1947. If I had more expertise in statistics and fisheries management I would have been able to run a more thorough statistical analyses between my two variables, invasive species establishment and fish populations, to look for correlations, either negative or positive. Given the timeframe and restraints of this research project, analyzing three different species catch per unit effort rates before and after an invasion of AIS sufficed for what I was aiming to learn.

Revisiting Literature Review

After conducting fish population research related to aquatic invasive species and interning with the Minnesota Department of Natural Resources I understand the literature I reviewed early in the process in a much deeper way. The concepts, data, and analysis included in the literature I reviewed make more sense to me now that I have worked with the MN DNR in Fisheries. I can apply what I learned through my experiences from hatchery work, population assessments, to otolith collection for a more extensive comprehension of fisheries management and research. Reviewing literature on fisheries management and research assisted me in forming my action research plan. I quickly realized that catch per unit effort was a valuable measurement in regards to fisheries population estimations and learned about survey techniques that involve this measurement that I would be able to use to collect data.

Aquatic invasive species in Minnesota. A lot of my literature review was about invasive carp and their impact on aquatic ecosystems because I knew that they were

present in Minnesota. I also reviewed literature on Eurasian watermilfoil and zebra mussels because I knew they were AIS that were present in the lakes I would be surveying. However, experiential learning while working with the MN DNR has taught me more than I would have been able to learn from any amount of literature review.

Carp. Less of my data collection pertained to common carp populations mainly because they already had established populations in Minnesota. There were common carp present in many of the lakes I surveyed this summer, but at very small CPUE rates. The rates were so low that this data was not included in my results because they did not yield any significant results. There were no patterns or correlations in the common carp populations observed in the lakes that I surveyed because they were present before the very first standardized lake survey conducted by the MN DNR in the late 1940s. This means I did not have adequate data to compare pre-carp establishment and post-carp establishment to native fish populations because the impact of this invasive species had already occurred. Due to these restraints out of my control, I focused my data analysis on the AIS that had established any time after 1948, when the MN DNR began conducting standardized lake surveys.

Some people, just like myself (prior to this thesis and internship with the MN DNR), do not know that there are multiple species of invasive carp. Due to their origin (being from Europe and Asia), all species of carp are considered exotic because they were not naturally found in North America. However, the main difference between common carp and grass, black, silver, and bighead carp is that only the common carp species has an established population in Minnesota. Zielinski & Sorensen's (2017) research on these carp species sparked my interest in carp behavior in the beginning of

my literature review. They conducted observations on silver, bighead, and common carp reactions and behavior in response to sound in the absence of visual cues (Zielinski & Sorensen, 2017). This research interested me because it stressed the significance of studying carp behavior and proposed the ability to create acoustic deterrents to be used to help control silver, bighead, and common carp populations in the Mississippi River. The MN DNR is currently monitoring and actively surveying to prevent these other carp species from establishing populations in Minnesota waters.

I participated in setting out gill nets over 1,000 feet long multiple times for short periods of time along the St. Croix River. We would pull the nets in, detangle the live fish, record the species, and release the fish back into the river. If a grass, black, silver, or bighead carp was caught, they would not be returned to the river. The same way we did not return common carp into the lakes we surveyed. If carp were caught in our nets they were killed and removed from the water because they are an invasive species. These surveys will be crucial to ecological evaluation if and when the other species of carp do establish populations in Minnesota's water. They will serve as a general population estimate and will allow future biologists to observe impact on native fish populations by conducting the same surveys and compare pre and post establishment of carp CPUE rates, just like I did for this project. This is a large task and a lot of water for the MN DNR to monitor alone, which is why environmental education efforts can make a large impact.

Zebra mussels. This was another large component of my literature review. Kanankege's et al. (2018) research on zebra mussel and Eurasian watermilfoil invasions in Minnesota were influential to my work and research process. After reading about his

research involving the two invasive species and their presence in Minnesota, I realized how critical the threat to Minnesota's water was. They calculated the probability of the species introduction by considering nearest infested body of water, boater traffic, and road access to conclude nearly 20% of the water bodies in Minnesota were considered at "high risk" of invasions by zebra mussels or Eurasian watermilfoil (Kanankege et al., 2018).

The two lakes I studied this summer that had zebra mussels had established populations within the past decade. My data did support my literature review in the sense that a decline was observed in fish populations post zebra mussel establishment. However, there also was outlier data that contradicted the literature review by showing increased northern pike populations following the establishment of zebra mussels in Lake Rebecca. Luckily, common ground has been made on many invasive species in Minnesota. Unluckily, the common ground settled upon today is that most scientists still do not have an exact answer how invasive species will impact an ecosystem but, it will not be positive.

For example, current research being done throughout Minnesota by the MN DNR Fisheries has yielded similar yet inconclusive results. An article published by Minnesota Public Radio focused on the research being conducted about zebra mussels, "Since zebra mussels were detected in Lake Carlos nine years ago, the zooplankton population has gone down 80 percent. Experts say water temperature and available food are the two biggest factors in the survival of young fish" (Gunderson, 2018). Most people like myself, would assume this could lead to a decline in fish populations. However, as I am learning it is always more complicated than that. Despite the dramatic loss of

zooplankton in Lake Carlos, the lake's fish populations appear to be surviving just fine at stable rates (Gunderson, 2018). The MN DNR employees conducting this survey even have reported increased populations of smallmouth bass, something they see commonly after an invasion of zebra mussels (Gunderson, 2018). This data seems to align with mine conducted in the east metro region, in the sense that not all of the data is following the same pattern. It seems some species population's decline, while others remain stable or even increase.

It is a great sign to see more research being done due to the lack of definitive answers on the impact AIS will have. AIS research will always be under pressure as invasive species continuously encroach into new habitat. In many ways, it is a race against time. It is a race between the invasive species and the invasive species research to find out how much damage it will likely cause in that given ecosystem. Once the negative impacts start to be observed, prevention and mitigation methods begin to be created and developed. This race against time and invasive species is in an attempt to protect the biodiversity of the world. It also can end up preventing major financial deficits caused by AIS invasions.

Collaborative efforts on research projects are trying to provide more answers about AIS impact since so much is still unknown. The MN DNR, UMN Duluth, Natural Resources Research Institute, and Voyageurs National Park have launched a project to try and quantify the impact zebra mussels and spiny water fleas have on food webs and fish growth rates. At this point, it is common knowledge that zebra mussels and spiny water fleas impact the food web directly by filtering algae from the water column, which reduces native zooplankton. However, the increased knowledge about this complex food

web and relationship can guide fisheries management decisions in the future. Understanding what makes walleye production successful after an invasion will allow managers to more precisely target early intervention tactics, more accurately predict walleye productions levels after an invasion, and better understand impacts (Hansen, 2018). These advances in research and better understanding will allow managers to better project realistic levels of walleye production and harvest (Hansen, 2018). In the long run, this research and these efforts will prevent further agony in the loss of walleye production and wasted resources in the future.

Aquatic invasive species education. While conducting my literature review I quickly learned that there is a major need for more research, specifically on the impact of AIS educational campaigns. The results of the research I reviewed throughout the Great Lakes region yielded positive correlations between AIS campaigns and recreational water users knowledge of AIS. Seekamp et al. (2016) demonstrated that boaters and anglers were most aware of the AIS campaign at 69%, most knowledgeable about AIS, and felt the most personal responsibility for AIS control. However, when they conducted focus study groups it became clear that they needed to enhance their campaign efforts with increased exposure (Seekamp et al., 2016). This observation seemed to become a trend throughout AIS education research during my literature review. AIS educational surveys could prove to be very beneficial in Minnesota to identify areas that lack exposure to AIS education. It would be valuable to be able to gauge the perception, identification, and knowledge of AIS in Minnesota residents.

However, this is no easy task. It would cost a lot of money, time, and effort in creating a survey and dispersing it to Minnesota residents. There would have to be ample

amounts of funding provided to pay for the employees conducting the research, the resources, and the products needed to complete the project. You would also have to account for a large percentage of surveys not being filled out and returned, which could lead to a gap in data. On the contrary though, throughout my literature review I learned that preventative efforts and methods are much more affordable than attempts at mitigation and removal once the AIS have established populations. This could be an appealing alternative to lakeshore property owners. A cost versus benefit analysis of enhancing preventative measures could provide some guidance for the future environmental education efforts, specifically regarding AIS in Minnesota.

Future Invasive Species Education

As already discussed, the MN DNR does not have enough man power alone to protect Minnesota from the numerous invasive species knocking on the door at the state borders, nor does the National Park Service, US Fish & Wildlife, or any other agency found here in Minnesota. No one person alone can stop invasive species from spreading. The true way to find success in this field and protect the water and land is with people power. Involving citizens and residents of Minnesota in the fight to prevent the spread of invasive species is the first step. This increases the potential number of invasive species being located, identified, and possibly removed before they are spread any further. This is where environmental education on the topic of invasive species can make a huge impact. For example, the MN DNR wants every grass, black, silver, and bighead carp reported that is caught by anglers. I fear that this is not happening, which negatively impacts the MN DNR's ability to accurately monitor the invasive carp presence in our water. With increased exposure and AIS environmental education efforts these messages could reach

more people who would be willing to contribute to the protection and conservation of Minnesota's wildlife.

My research, data, and analysis could be used to support invasive species educational lesson plans in the Midwest. It gives examples of data collected in the Metro Area of the Twin Cities and how invasive species have altered the native fish populations since their establishment. This data could be accompanied with invasive species identification lessons about the species studied in my research. For example, how to tell the difference between Eurasian watermilfoil and northern watermilfoil is very minute and found in the number of leaflet pairs per leaf. However, these details are the key to creating an effective invasive species educational campaign.

An example of a brief elementary education lesson plan (I created by using a Hamline University lesson plan template) derived from my research on AIS and fish populations can be found in Appendix B. Next Generation Science standards recommend a lesson plan that follows the Five E's of science instruction: Engage, Explore, Explain, Elaborate, Evaluate (Five Es of Science Instruction, 2018).

This lesson is a relatively simple and easy example of how to use my AIS data in an elementary education lesson plan in environmental education. The students become *engaged* with the lesson by learning about many of the fish living in the nearby lakes and expressing what they already know. The students *explore* the major concepts by playing a hands on fish food web reenactment game. After the exploration of the concepts in the activity, the teacher *explains* the connection between the animals and food/resources available in the aquatic ecosystem. The students *elaborate* on what they have learned by sharing their thoughts in discussion about what changed once the zebra mussels invaded.

Lastly students and teachers *evaluate* the new skills and understandings developed during the lesson about how AIS impact native species. Current research and data should always be referenced while creating environmental lesson plans because science is always evolving. It also can expose students to future career paths.

In using this data and research project as a whole, it may act as a recruitment tool for not only MN DNR Fisheries, but also the field of environmental science. Many years ago most of us working in the environmental, biological, and natural science field recall specific moments that sparked our initial interest and guided us in this direction. At an older age and higher education level, such as high school, organizing a lesson plan around AIS in Minnesota and using my research as supporting data may expose students to careers and opportunities in this field.

Conclusion

Moving forward from this experience, I am well aware of the restraints within the environmental field that usually stem from a lack of funding and financial support. As frustrating and as disappointing it may be, in the end it will be the determined servants of the biological field researching and protecting our ecosystems who make the difference. At this point, I am very pleased to see further research projects being conducted and set up by the MN DNR about invasive species and how they impact native species. I can see from my literature review and my research, that while trends appear to be negative for invasive species interactions with native species, much is still left unknown.

I still have questions like can fish adapt to a new diet when resources are decreased due to invasive species? Is the changing climate weakening our native species, making invasion of exotic species easier? Does establishment of a new invasive species

reduce reproduction rates and/or survival rates of young of the year? What role do hybrids (crossbreeding of native species and invasive species) play in the ecosystem? These questions will require further research on AIS impact. As exotic invasions and the climate changes, research must continue to guide us and provide us with answers. I plan on applying what I have learned from this experience into my future environmental science career.

Invasive species education is crucial to preserving the pristine ecosystems found around the world. To acknowledge that we are not certain how animal and plant species react to exotic invasions will drive us, as ecologists, to engage in further research in search of answers. This research is pivotal in educating communities about invasive species. Invasive species education is important for not just one reason alone, but for a multitude of reasons that will continue to grow in severity if not addressed. Local residents need to be aware of what is threatening their natural ecosystems so they can participate in active prevention methods. At the community level, a lot of information is spread by word of mouth, so empowering residents at the local level can be helpful to spread conservation messages.

If we do not work together towards increasing environmental education efforts we might have to say goodbye to the things we love the most. Invasive species threaten the biodiversity and health of our lakes and rivers, our fishing, our majestic old growth forests, our hunting, our parks, and most other natural characteristics that make North America an immaculate place to live. Even though we have found ourselves in a technological age where humans thrive successfully in concrete jungles, there is one factor that will always remain constant. Survival of mankind is contingent on the world's

ability to provide us with resources. I have pondered time after time what the world would be like without rainforests, coral reefs, the polar ice caps, and so on. I know it would not be as good as it is today without those amazing features, however, I only offer one answer. As an environmentalist, I want the future generations to be able to tangibly learn about these plants, animals, ecosystems, and resources as a crucial part of our world, not as a crucial part of our history.

APPENDIX A

Additional lakes infested with Eurasian Watermilfoil:

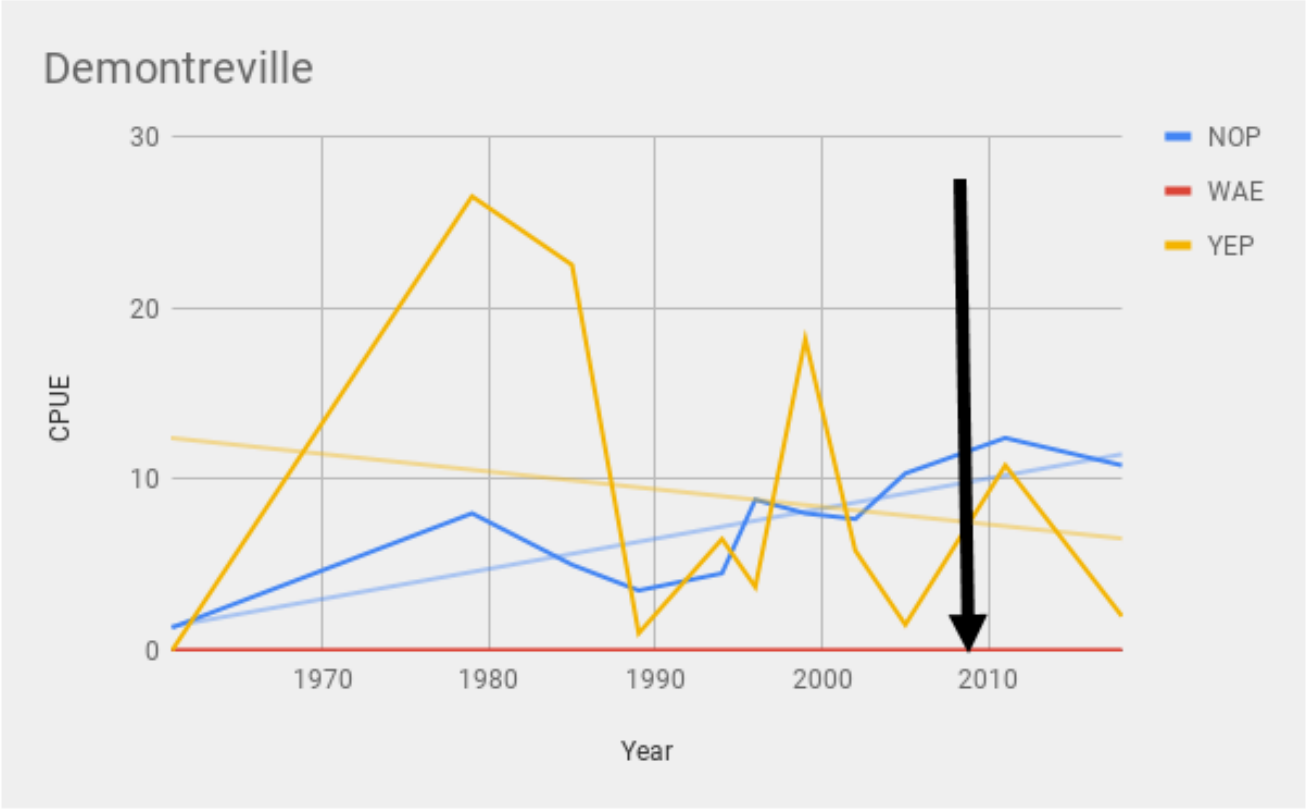

Figure 11. Demontreville Lake became infested with EWM in 2009, represented by the black arrow. Five gillnets were set on Demontreville Lake in June 2018. The CPUE results were as follows:

Year	NOP	WAE	YEP
2016	12.4	0	10.8
2018	10.8	0	2

Table 8. There is a decrease in CPUE rates of all three species in comparison of the last two surveys.

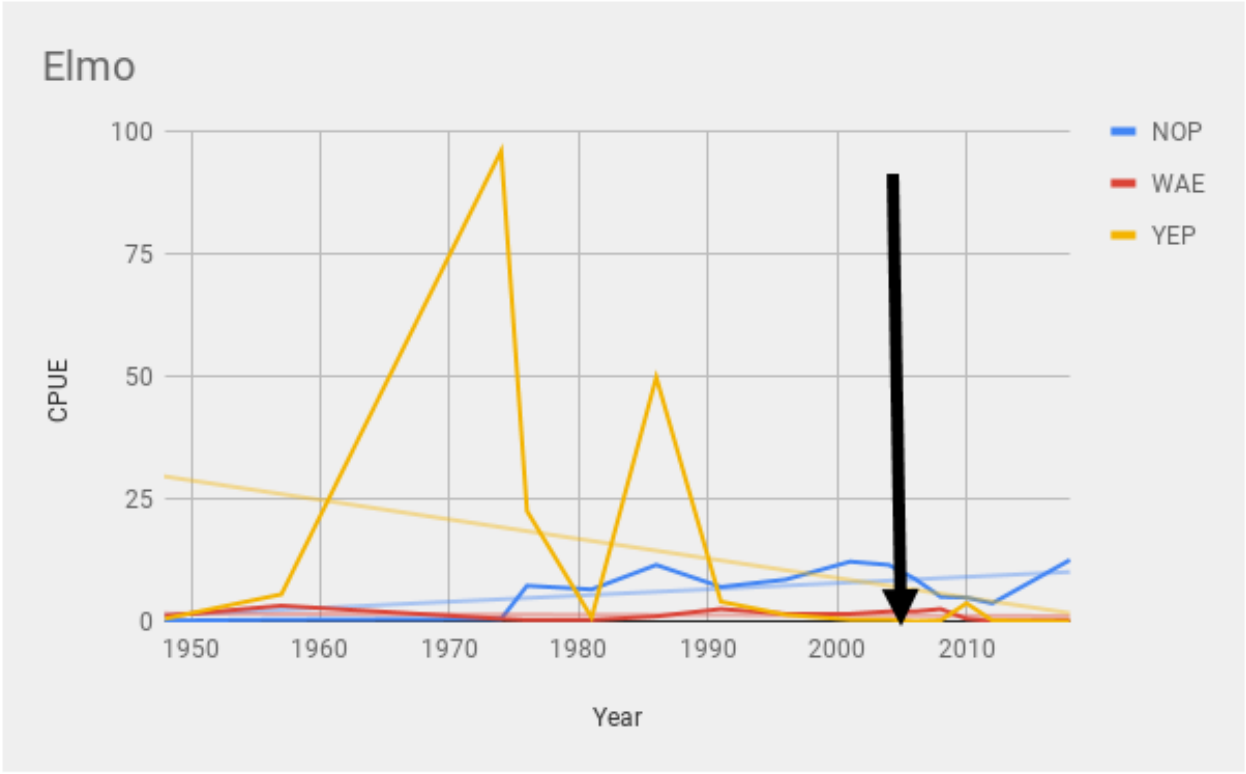

Figure 12. Lake Elmo became infested with EWM in 2006, represented by the black arrow. Six gillnets were set on Lake Elmo in June 2018. The CPUE results were as follows:

Year	NOP	WAE	YEP
2016	3.67	0	0.17
2018	12.5	0.17	0

Table 9. There is an increase in NOP and very little variance between WAE and YEP CPUE rates in the last two surveys.

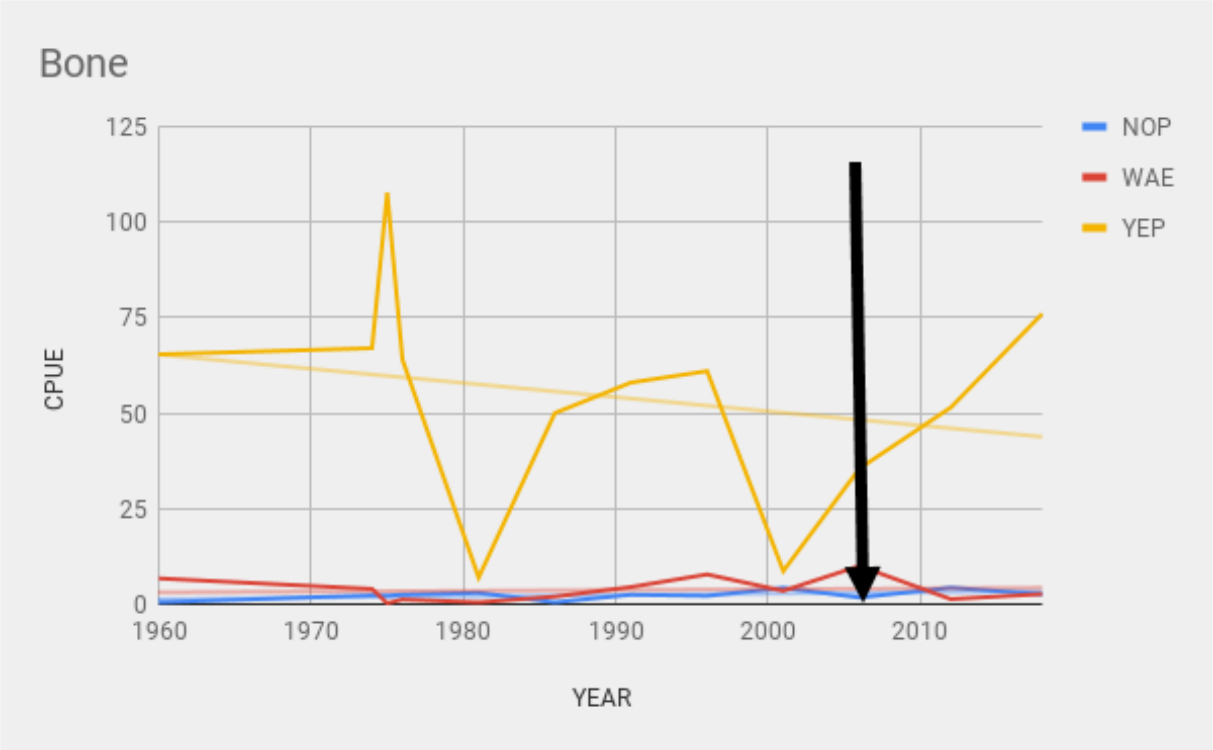

Figure 13. Bone Lake became infested with EWM in 2006, represented by the black arrow. Five gillnets were set on Bone Lake in June 2018. The CPUE results were as follows:

Year	NOP	WAE	YEP
2016	4.33	1.33	51.5
2018	2.6	2.67	76

Table 10. There is a decrease in NOP, but an increase in WAE and YEP CPUE rates over the last two surveys.

APPENDIX B

Aquatic Invasive Species Environmental Education Lesson

Lesson title, length of time, age of participants, and other notes as needed *(ex. Location, time of day—if relevant to content or focus of lesson)*	You Can Run But You Can't Hide From ***INVASIVE SPECIES***! **Time:** 60 minute lesson plan **Number of students:** 20 students **Age of students:** 8-10 years old **Location:** ANY classroom, nature center, or outdoor space
Rationale: *(What's the reason for this lesson?)*	The main reason for this lesson plan is to introduce the students to aquatic invasive species (AIS) found in Minnesota and how they impact our ecosystems and native species.
Lesson objectives: *(What will participants do, and what will they experience/learn?)*	After learning about AIS through presentation information, videos, and books the students will act out components of a complex food web reaction to an invasive species.
Background information: *(the content and concepts needed for the teacher to deliver the lesson)*	All of the content and concepts for this lesson plan can be found online on the MN DNR invasive species webpage and from Alexandra Crofts' MAEd Thesis: *Why is Invasive Species Education Important* in the Bush Library at Hamline University. Ex: An introduction of zebra mussels into a lake will impact native fish populations by decreasing available resources. This happens by zebra mussels filter feeding algae out of the water column, which is what zooplankton feed on. Since there is less algae for zooplankton to feed, there is a decline in zooplankton populations, which many fish species and almost all young fish survive on. This decrease in resources might lead to a decrease in fish populations or growth rates.
Materials/preparation: *(list all materials needed, including quantities and any preparation that must be done ahead of time)*	**1.** Laminated character cards of fish and AIS; hole punched with string necklace for students to wear during activity: seven northern pike pictures, seven yellow perch pictures, seven walleye pictures, ten zebra mussel pictures. **2.** 30-40 soft foam (any color) balls **3.** 4 buckets

Safety or special considerations: *(list any anticipated accommodations that might be necessary)*	There must be a designated area to perform this activity since it involves physical engagement and students running. Choose an area with open spaces that lacks any dangerous objects and even ground.
Procedure:	**1.** Randomly assign students fish species teams by handing out cards (first round does not include zebra mussels) and tell them which bucket coordinates with each species **2.** Pile or scatter balls around designated area for activity **3.** Time 1st round for 3 minutes; students are trying to collect as many balls as possible into their species bucket **4.** Record each species number of balls collected at the end of the round and repeat 2nd round for 3 minutes. **5.** Average out the total of both trials for all 3 species of fish (northern pike, yellow perch, walleye) and record it on the board. **6.** In the next round remove ten students fish cards (3-4 from each fish species) and give them zebra mussels cards and a corresponding bucket to collect their balls **7.** Repeat 2 more rounds of 3 minutes each and record averages per species. **8.** Clean up activity and begin discussion. Note the decline in balls collected by each fish species and amount collected by zebra mussels. The balls represent the resources found in the aquatic ecosystem we recreated.
Wrap-up/conclusion:	Finish up the lesson plan by explaining the chain reaction exemplified in the game that was just played. Each fish team collected less balls in the two rounds when the zebra mussels were present due to increased competition for resources. Discuss how it becomes harder for the fish species to collect their balls, which represent food for them. **Ask students follow up questions:** Was it more or less stressful to collect balls/resources when the zebra mussels entered the game? Did they have more or less fish teammates once

	the zebra mussels invaded? Do you think it is hard for fish to find food once zebra mussels invade?

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